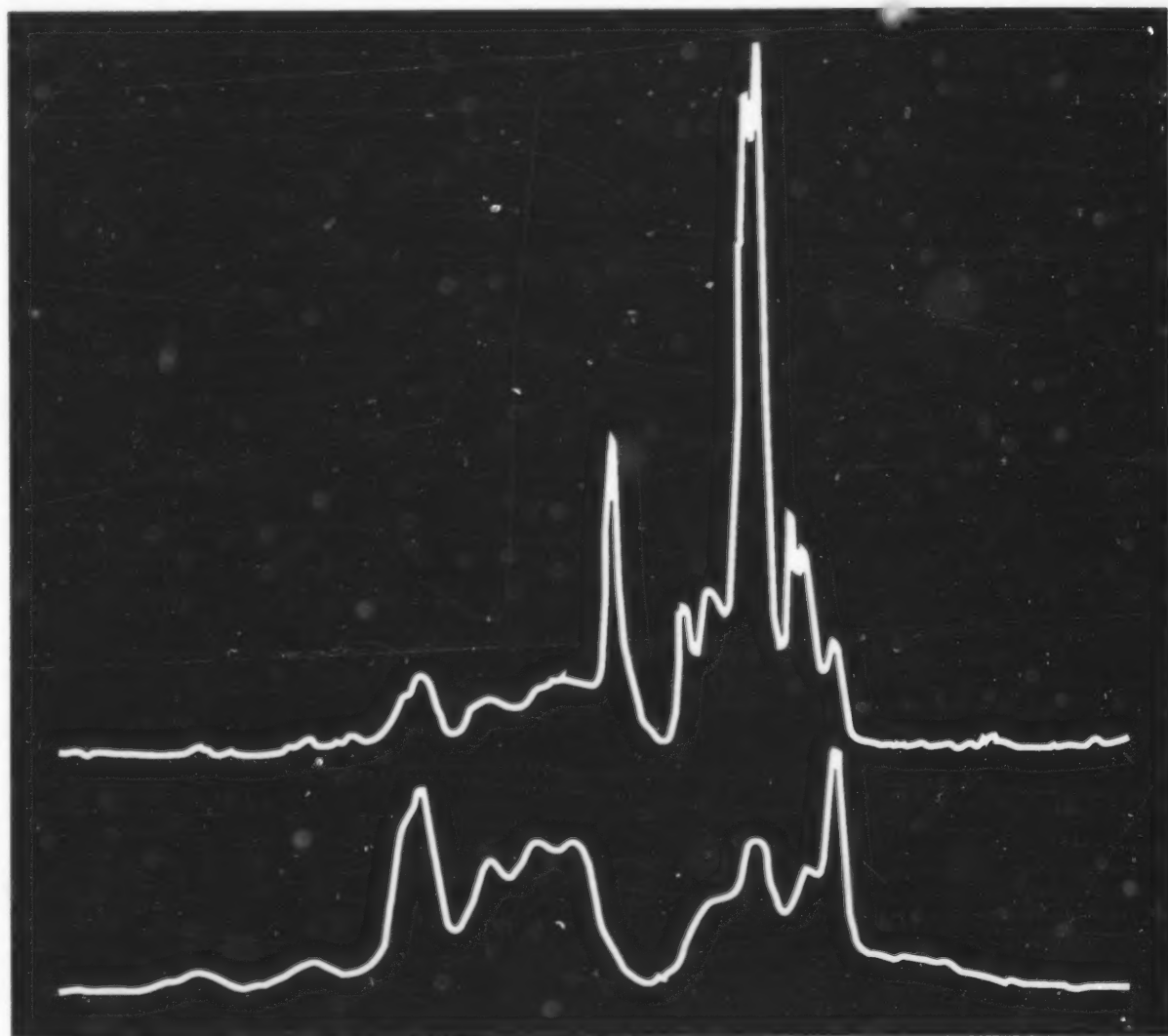




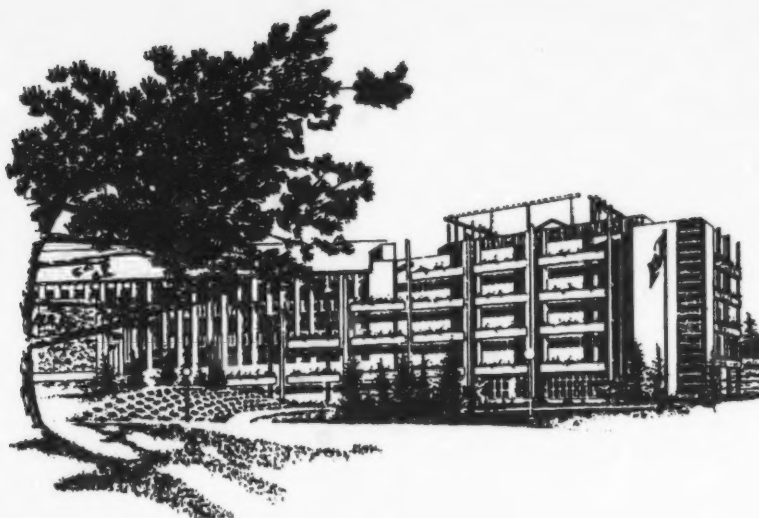
A bibliography of NMR applications for forestry research

Pacific Forestry Centre - Information Report BC-X-322

Caroline M. Preston and Ann C. M. Rusk



Forestry Canada Forêts Canada



The Pacific Forestry Centre is one of six regional and two national establishments of Forestry Canada. Situated in Victoria with a district office in Prince George, the Pacific Forestry Centre cooperates with other government agencies, the forest industry, and educational institutions to promote the wise management of the forest resources of British Columbia and the Yukon.

The Pacific Forestry Centre undertakes research in response to the needs of the various managers of the forest resource. The results of this research are distributed in the form of scientific and technical reports and other publications.

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Forestry Canada
Pacific and Yukon Region
Pacific Forestry Centre

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Abstract

More widespread application of nuclear magnetic resonance (NMR) spectroscopy to forestry research could have many benefits. However, forestry researchers are largely uninformed about the technique, or perceive it to be too expensive and sophisticated for forestry needs. This bibliography lists over 450 recent references to the end of 1989, with a few publications which were available early in 1990. These are arranged in subject categories relevant to forestry problems, including general reviews of biological NMR, applications to bacteria, fungi, algae and higher plants, distribution and physical properties of water in plants, physiology and polymer chemistry of insects, and applications to wood, soil, glyphosate, and analytical biochemistry. The NMR techniques cover a wide range of applications, including solutions and solids, conventional spectroscopy, and imaging. The information collected here should enable forestry researchers to design novel and effective NMR approaches to problems and to prepare grant applications to obtain the necessary NMR instrumentation. An author index and a brief introduction to some basic NMR concepts are provided.

Résumé

L'application à plus grande échelle de la spectroscopie de résonance magnétique nucléaire (RMN) aux recherches en foresterie aurait de nombreux avantages. Toutefois, la plupart des chercheurs en foresterie connaissent peu cette technique ou la perçoivent comme une technique trop dispendieuse et trop perfectionnée pour répondre aux besoins dans ce domaine. Cette bibliographie énumère plus de 450 publications récentes parues jusqu'à la fin de 1989 et dont quelques-unes étaient disponibles au tout début de 1990. Ces titres sont énumérés par sujets applicables aux problèmes de la foresterie et comprennent des études générales sur l'utilisation de la RMN en biologie, des applications aux bactéries, aux champignons, aux algues et aux plantes supérieures, la distribution et les propriétés physiques de l'eau dans les plantes, la physiologie et la chimie des polymères chez les insectes, et des applications au bois, au sol, au glyphosate et à la biochimie analytique. Les techniques de RMN peuvent être appliquées dans de nombreux domaines, dont les solutions et les solides, la spectroscopie classique et l'imagerie. Les informations compilées dans cette bibliographie devraient permettre aux chercheurs en foresterie de concevoir des méthodes nouvelles et efficaces pour résoudre des problèmes à l'aide de la résonance magnétique nucléaire et de préparer leur demande de subvention en vue de se procurer l'appareillage de RMN nécessaire. La bibliographie renferme un index des auteurs, ainsi qu'une brève introduction à certaines notions de base de la RMN.

Introduction

Since 1970, developments in nuclear magnetic resonance (NMR) spectroscopy have facilitated its application to many areas of applied science far beyond its original utilization for organic structure determination in chemistry. These areas include biology, medicine, agriculture, geochemistry and materials science. There has, however, been little penetration of the technique into forestry research. This is unfortunate because there are many forestry problems which could be addressed using the information available from NMR techniques. This underutilization is not due to technical limitations, but to historical factors. Forestry research has traditionally not been heavily dependent on the more capital-intensive chemical technologies, such as GC-MS, pyrolysis-MS, NMR and ICP. There are few researchers with interest or expertise in both forestry and NMR or other types of sophisticated chemical analysis techniques, and little opportunity for graduate students to work in these areas.

The publication of this bibliography marks a step toward better utilization of NMR in forestry research. In 1990, a Forestry Canada NMR facility is being established at the Pacific Forestry Centre in Victoria, British Columbia. The laboratory will be based on a 250 MHz superconducting spectrometer for solution NMR, including variable-temperature and multinuclear capability. This instrument will be one of a handful worldwide devoted to forestry research, and also one of the few available for soils applications.

The NMR Technique

The NMR phenomenon occurs because some nuclei have an inherent magnetic moment or spin. In a magnetic field, which is provided by the magnet of an NMR spectrometer, such nuclei split into populations with different energies, the energy gap between adjacent levels being proportional to the applied field. For nuclei with a spin of 1/2 such as ^1H , ^{13}C , ^{15}N , ^{19}F , and ^{31}P , there are two energy levels. At equilibrium, there is a slight excess population (determined by the Boltzmann equation) in the lower state, in which the magnetic moment is aligned with the external magnetic field. Perturbation of the spin system by a radiofrequency (RF) pulse whose energy corresponds to that of the energy gap (the Larmor frequency) induces transitions between the two levels, and these effects can be detected and processed to produce NMR spectra or images.

The size of the energy gap between spin levels (or the Larmor frequency) depends, first, on the inherent magnetic moment and magnetogyric ratio of the nu-

cleus. It is also proportional to the applied field, and magnet field strengths are often designated by the Larmor frequency of ^1H ; fields currently used in NMR range up to 600 MHz. Third, the exact field strength at the nucleus is affected by its chemical environment, primarily the type of chemical bond in which it participates, and to a lesser extent by other factors, such as solvent, pH, temperature, and viscosity. This results in NMR signals with a range of "chemical shifts" away from the basic Larmor frequency of an isolated nucleus. NMR spectra are also characterized by coupling constants (J-values), integrated areas (I), and relaxation times. The splittings, or couplings, arise from the interactions of nuclei in covalently-bonded structures, while the integrated areas are proportional to the number of spins of each type. The information derived from these three parameters is extremely useful in the elucidation of molecular structures.

NMR spectra are also characterized by relaxation times, which are determined in time-dependent experiments. These are time constants for the return of the system to equilibrium after a perturbation, such as an RF pulse. Measurements of relaxation times are also used to derive structural information, but they are particularly sensitive to molecular motion. Relaxation phenomena are important for another reason. NMR relaxation is relatively slow, on the order of seconds, and this constrains repetition rates for acquisition of spectra. At the same time, this slow relaxation, or relative isolation of the spin system from the lattice, means that spin populations can be manipulated in a variety of pulse sequences. These include the so-called two-dimensional (or "2D") experiments, which provide far more information than conventional (or "1D") spectra. It also allows relaxation phenomena to be exploited in special pulse sequences to enhance contrast in NMR imaging.

It is only within the last 10 to 15 years that developments in NMR technology have made possible its routine application to areas such as plant physiology and geochemistry. These developments include superconducting magnets with high fields, Fourier transform (FT) techniques for data acquisition and manipulation, CPMAS (Cross-Polarization Magic-Angle Spinning) methods for obtaining well resolved spectra of solids, and spatially resolved NMR to obtain two-dimensional and three-dimensional images. All of these developments have made possible the routine application of NMR to samples which are structurally complex, heterogeneous, very dilute, solids, gels, or living organisms, from single cells to large mammals. They have also enhanced the potential for utilization of nuclei which are less sensitive or less abundant, such as ^2H , ^{13}C , ^{15}N , ^{23}Na , ^{27}Al , ^{29}Si and ^{31}P .

The Bibliography

This bibliography lists over 450 references in diverse areas relevant to forestry problems. The literature was searched to the end of 1989, but a few early publications from 1990 are also included. In many areas, for which reports on forestry applications were limited or non-existent, relevant examples have been drawn from other areas to indicate the feasibility or potential for forestry applications. Both conventional (spectroscopic) NMR of solution and solid-state samples, and spatially resolved (imaging) NMR are included. There is an emphasis on *in vivo* biology, and on materials with complex or heterogeneous structures. Within each subject division, references are arranged alphabetically, but the complete set has been numbered consecutively. An author index is provided.

Coverage was limited in the more conventional areas of organic structure determination, as these are highly developed and well-documented elsewhere. However, selected publications are listed in a few topic areas to indicate the level of sophistication now possible with NMR, and to guide readers to other sources. These areas are (i) structural analysis of proteins and natural products, and (ii) organic analysis, including direct analysis of mixtures and aqueous solutions. NMR applications in wood processing are also highly developed, and only a few examples are given. References have generally been restricted to material which is fairly recent and readily available in journals or books. It is hoped that the information collected here will assist forestry researchers in designing novel and effective NMR approaches to problem-solving, and in preparing grant applications and proposals to obtain the necessary NMR instrumentation.

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I. Chemical Applications - Structural Elucidation

I (a). Proteins

- 1 Bax, A. 1989. Two-dimensional NMR and protein structure. *Ann. Rev. Biochem.* 58:223-256.
- 2 Gronenborn, A.M.; Clore, G.M. 1990. Protein structure determination in solution by two-dimensional and three-dimensional nuclear magnetic resonance spectroscopy. *Anal. Chem.* 62:2-15.
- 3 Kaptein, R.; Boelens, R.; Scheek, R.M.; van Gunsteren, W.F. 1988. Protein structures from NMR. *Biochemistry* 27:5389-5395.
- 4 Marion, D.; Driscoll, P.C.; Kay, L.E.; Wingfield, P.T.; Bax, A.; Gronenborn, A.M.; Clore, G.M. 1989. Overcoming the overlap problem in the assignment of ^1H NMR spectra of larger proteins by use of three-dimensional heteronuclear ^1H - ^{15}N Hartmann-Hahn-multiple quantum coherence and nuclear Overhauser-multiple quantum coherence spectroscopy: application to Interleukin 1b. *Biochemistry* 28:6150-6156.
- 5 Motta, A.; Morelli, M.A.C.; Goud, N.; Temussi, P.A. 1989. Sequential ^1H NMR assignment and secondary structure determination of salmon calcitonin in solution. *Biochemistry* 28:7996-8002.
- 6 Preston, C.; Preston, J.M. 1986. Proton nuclear magnetic resonance studies of soybean lectin-monosaccharide interactions: computer analysis of complex binding behavior. *Arch. Biochem. Biophys.* 247:190-200.
- 7 Purisima, E.O.; Blackwell, B.A. 1990. Protein structure determination by nuclear magnetic resonance spectroscopy. Pages 187-226 (Chapter 9) in S.A. Narang, editor. *Protein Engineering Approaches from the Classical to the Genetic*. Boston, Butterworth.

I (b). Natural Products

- 8 Appanna, V.D.; Preston, C.M. 1987. Manganese elicits the synthesis of a novel exopolysaccharide in an arctic *Rhizobium*. *Fed. Eur. Biochem. Soc. Lett.* 215:79-82.
- 9 Blackwell, B.A.; Miller, J.D.; Greenhalgh, R. 1985. ^{13}C NMR study of the biosynthesis of toxins by *Fusarium graminearum*. *J. Biol. Chem.* 260:4243-4247.
- 10 Blunt, J.W.; Munro, M.H.G.; Swallow, W.H. 1979. Carbon-13 N.M.R. analysis of tutin and related substances: application to the identification of minor components of toxic honey. *Aust. J. Chem.* 32:1339-1343.
- 11 Blunt, J.W.; Steel, P.J. 1982. The measurement of $^1J_{\text{CH}}$ values from broad-band decoupled ^{13}C N.M.R. spectra: application to the spectral assignment of *cis*-pinon-2-ol. *Aust. J. Chem.* 35:2561-2566.
- 12 Girault, J.P.; Lafont, R. 1988. The complete ^1H -NMR assignment of ecdysone and 20-hydroxyecdysone. *J. Insect Physiol.* 34:701-706.
- 13 Greenhalgh, R.; Blackwell, B.A.; Savard, M.E. 1989. The NMR spectra of trichothecenes and related fungal metabolites. *Tetrahedron* 45:2373-2383.

-
- 14 Greenhalgh, R.; Blackwell, B.A.; Savard, M.; Miller, J.D.; Taylor, A. 1988. Secondary metabolites produced by *Fusarium sporotrichioides* DAOM 165006 in liquid culture. *J. Agric. Food Chem.* 36:216-219.
 - 15 Greenhalgh, R.; Fielder, D.A.; Morrison, L.A.; Charland, J.-P.; Blackwell, B.A.; Savard, M.E.; ApSimon, J.W. 1989. Secondary metabolites of *Fusarium* species: apotrichothecene derivatives. *J. Agric. Food Chem.* 37:699-705.
 - 16 Greenhalgh, R.; Meier, R.-M.; Blackwell, B.A.; Miller, J.D.; Taylor, A.; ApSimon, J.W. 1986. Minor metabolites of *Fusarium roseum* (ATCC 28114). 2. *J. Agric. Food Chem.* 34:115-118.
 - 17 Jones, G.P.; Naidu, B.P.; Paleg, L.G.; Tiekink, E.R.T.; Snow, M.R. 1987. 4-hydroxy-N-methylproline analogues in *Melaleuca* spp. *Phytochemistry* 26:3343-3344.
 - 18 Lauren, D.R.; Ashley, A.; Blackwell, B.A.; Greenhalgh, R.; Miller, J.D.; Neish, G.A. 1987. Trichothecenes produced by *Fusarium crookwellense* DAOM 193611. *J. Agric. Food Chem.* 35:884-889.
 - 19 Manville, J.F.; Fraser, T.; Tracey, A.S. 1989. Characterization of lasiocarpenonol and conformation of four sesquiterpenoids from alpine fir. *Phytochemistry* 28:3073-3080.
 - 20 Manville, J.F.; Tracey, A.S. 1989. Chemical differences between alpine firs of British Columbia. *Phytochemistry* 28:2681-2686.
 - 21 McCallion, R.F.; Cole, A.L.J.; Walker, J.R.L.; Blunt, J.W.; Munro, M.H.G. 1982. Antibiotic substances from New Zealand plants. II. Polygodial, an anti-candida agent from *Pseudowintera colorata*. *Planta Medica* 44:134-138.
 - 22 McIntyre, D.D.; Ho, C.; Vogel, H.J. 1990. One-dimensional nuclear magnetic resonance studies of starch and starch products. *Die Stärke/Starch*, in press.
 - 23 McIntyre, D.D.; Vogel, H.J. 1989. Complete assignment of the ¹H-NMR spectrum of stachyose by two-dimensional NMR spectroscopy. *J. Nat. Prod.* 52:1008-1014.
 - 24 McIntyre, D.D.; Vogel, H.J. 1990. Two-dimensional nuclear magnetic resonance studies of starch and starch products. *Die Stärke/Starch*, in press.
 - 25 Ryder, M.H.; Tate, M.E.; Jones, G.P. 1984. Agrociniopine A, a tumor-inducing plasmid-coded enzyme product, is a phosphodiester of sucrose and L-arabinose. *J. Biol. Chem.* 259:9704-9710.
 - 26 Savard, M.E.; Blackwell, B.A.; Greenhalgh, R. 1987. An ¹H nuclear magnetic resonance study of derivatives of 3-hydroxy-12,13-epoxytrichothec-9-enes. *Can. J. Chem.* 65:2254-2261.
 - 27 Savard, M.E.; Blackwell, B.A.; Greenhalgh, R. 1989. The role of ¹³C-labelled trichodiene and bazzanene in the secondary metabolism of *Fusarium culmorum*. *J. Nat. Prod.* 52:1267-1278.
 - 28 Savard, M.E.; Greenhalgh, R. 1987. Synthesis and NMR analysis of new natural trichothecenes. *J. Nat. Prod.* 50:953-957.
 - 29 Seto, H.; Furihata, K.; Guangyi, X.; Xiong, C.; Deji, P. 1988. Assignments of the ¹H- and ¹³C-NMR spectra of four lycopodium triterpenoids by the application of a new two-dimensional technique, heteronuclear multiple bond connectivity (HMBC). *Agric. Biol. Chem.* 52:1797-1801.
-

II. Chemical Applications - Analytical

II (a). Analytical ^1H NMR in Aqueous Solutions

- 30 Connor, S.; Nicholson, J.K.; Everett, J.R. 1987. Chemical-exchange and paramagnetic T_2 relaxation agents for water suppression in spin-echo proton nuclear magnetic resonance spectroscopy of biological fluids. *Anal. Chem.* 59:2885-2891.
- 31 Eads, T.M.; Bryant, R.G. 1986. High-resolution proton NMR spectroscopy of milk, orange juice, and apple juice with efficient suppression of the water peak. *J. Agric. Food Chem.* 34:834-837.
- 32 Eads, T.M.; Kennedy, S.D.; Bryant, R.G. 1986. Solvent suppression in high-resolution proton nuclear magnetic resonance based on control of transverse relaxation rate. *Anal. Chem.* 58:1752-1756.
- 33 Rabenstein, D.L.; Fan, S. 1986. Proton nuclear magnetic resonance spectroscopy of aqueous solutions: complete elimination of the water resonance by spin-spin relaxation. *Anal. Chem.* 58:3178-3184.
- 34 Tellier, C.; Guillou-Charpin, M.; Grenier, P.; Le Botlan, D. 1989. Monitoring alcoholic fermentation by low-resolution pulsed nuclear magnetic resonance. *J. Agric. Food Chem.* 37:988-991.

II (b). Hyphenated Analytical Techniques

- 35 Allen, L.A.; Glass, T.E.; Dorn, H.C. 1988. Direct monitoring of supercritical fluids and supercritical chromatographic separations by proton nuclear magnetic resonance. *Anal. Chem.* 60:390-394.
- 36 Allen, L.A.; Spratt, M.P.; Glass, T.E.; Dorn, H.C. 1988. Directly coupled liquid chromatography/fluorine-19 Fourier transform nuclear magnetic resonance. *Anal. Chem.* 60:675-679.
- 37 Ha, S.T.K.; Wilkins, C.L.; Abidi, S.L. 1989. Analysis of antimycin A by reversed-phase liquid chromatography/nuclear magnetic resonance spectrometry. *Anal. Chem.* 61:404-408.
- 38 Wade, C.G.; Johnson, R.D.; Philson, S.B.; Stouse, J.; McEnroe, F.J. 1989. Changing views of NMR: automated high-resolution NMR with a sample changer. *Anal. Chem.* 61:107A.

II (c). Direct Analysis of Mixtures

- 39 Brekke, T.; Aksnes, D.W.; Sletten, E.; Stöcker, M. 1988. Solvent shifts and component identification of hydrocarbon mixtures by carbon-13 nuclear magnetic resonance spectrometry. *Anal. Chem.* 60:591-596.
- 40 Jurs, P.C.; Sutton, G.P.; Ranc, M.L. 1989. Carbon-13 NMR spectral simulation. *Anal. Chem.* 61:1115A-1122A.
- 41 Laude, D.A. Jr.; Wilkins, C.L. 1987. Identification of mixture components in organic waste materials by carbon-13 nuclear magnetic resonance. *Anal. Chem.* 59:576-581.
- 42 Low, N.H.; Brisbane, T.; Bigam, G.; Sporns, P. 1988. Carbon-13 nuclear magnetic resonance for the qualitative and quantitative analysis of structurally similar disaccharides. *J. Agric. Food Chem.* 36:953-957.

-
- 43 Sparling, M.L.; Zidovetzki, R.; Muller, L.; Chan, S.I. 1989. Analysis of membrane lipids by 500 MHz ^1H NMR. *Anal. Biochem.* 178:67-76.
- 44 Wilkins, C.L.; Ha, S.T.K.; Lee, R.W.K. 1988. Direct mixture analysis using carbon-proton J -resolved nuclear magnetic resonance. *Anal. Chem.* 60:1055-1059.

II (d). Analytical Applications to Plants

- 45 Blunt, J.W.; Munro, M.H.G. 1976. An automated procedure for qualitative and quantitative analysis of mixtures by means of carbon magnetic resonance spectroscopy: applications to carbohydrate analysis. *Aust. J. Chem.* 29:975-986.
- 46 Coombe, B.G.; Jones, G.P. 1983. Measurement of the changes in the composition of developing unde-tached grape berries by using ^{13}C NMR techniques. *Phytochemistry* 22:2185-2187.
- 47 Jones, G.P.; Naidu, B.P.; Starr, R.K.; Paleg, L.G. 1986. Estimates of solutes accumulating in plants by ^1H nuclear magnetic resonance spectroscopy. *Aust. J. Plant Physiol.* 13:649-658.
- 48 Kainosho, M. 1976. ^{13}C NMR studies of the intact plant tissues. Cytoplasmic aucubin and sucrose in a single seed of *Aucuba japonica*. *Tetrahed. Lett.* 47:4279-4282.
- 49 Kainosho, M.; Ajisaka, K. 1978. Carbon-13 nuclear magnetic resonance spectra of gross plant tissues containing starch. *Tetrahed. Lett.* 18:1563-1566.
- 50 Meredith, P.; Dengate, H.N.; Hennessy, W.; Blunt, J.W.; Hartshorn, M.P.; Munro, M.H.G. 1980. Sac-charides of developing wheat grain determined by ^{13}C NMR spectroscopy. *Starch/Stärke* 32:198-205.
- 51 Tamate, J.; Bradbury, J.H. 1985. Determination of sugars in tropical root crops using ^{13}C N.M.R. spectroscopy: comparison with the H.P.L.C. method. *J. Sci. Food Agric.* 36:1291-1302.
- 52 Thomas, T.H.; Ratcliffe, R.G. 1985. ^{13}C NMR determination of sugar levels in storage roots of carrot (*Daucus carota*). *Physiol. Plant* 63:284-286.
- 53 Visintainer, J.; Hirst, R.C. 1986. ^{13}C -NMR Determination of rubber content in guayule bushes. Pages 148-168 in H.F. Linskens, and J.F. Jackson, editors. *Modern Methods of Plant Analysis Series, Vol. 2, Nuclear Magnetic Resonance*. Berlin, Springer-Verlag. 215 p.

III. Biological Applications

III (a). Biological NMR - Reviews and Summaries

- 54 Becker, E.D.; Fisk, C.L. 1987. NMR: physical principles and current status as a biomedical technique. *Ann. N. Y. Acad. Sci.* 508:1-9.
- 55 Belton, P.S.; Ratcliffe, R.G. 1985. NMR and compartmentation in biological tissues. *Prog. NMR Spec-trosc.* 17:241-279.
- 56 Chen, C.-N.; Hoult, D.I. 1989. *Biomedical Magnetic Resonance Technology*. Bristol, Adam Hilger, IOP Publishing Ltd. 344 p.

-
- 57 Cohen, S.M., editor. 1987. *Annals of the New York Academy of Science*, Vol. 508, Physiological NMR spectroscopy: from isolated cells to man. 537 p.
- 58 Gupta, R.K., editor. 1987. *NMR Spectroscopy of Cells and Organisms*, 2 volumes. Boca Raton, Fla., CRC Press Inc. Vol 1, 168 p.; Vol 2, 147 p.
- 59 Norton, R.S. 1980. ^{13}C NMR studies of intact cells and tissue. *Bull. Mag. Res.* 3:29-48.
- 60 Pfeffer, P.E.; Gerasimowicz, W.V., editors. 1989. *Nuclear Magnetic Resonance in Agriculture*. Boca Raton, Fla., CRC Press, Inc. 441 p.
- 61 Roberts, J.K.M.; Jardetzky, O. 1981. Monitoring of cellular metabolism by NMR. *Biochim. Biophys. Acta* 639:53-76.
- 62 Vogel, H.J.; Brodelius, P.; Lilja, H.; Lohmeier-Vogel, E.M. 1987. Nuclear magnetic resonance studies of immobilized cells. *Meth. Enzymol.* 135:512-528.

III (b). Plant NMR - Reviews and Summaries

- 63 Linskens, H.F.; Jackson, J.F., editors. *Modern Methods of Plant Analysis*, Vol. 2, Nuclear Magnetic Resonance. Berlin, Springer-Verlag. 215 p.
- 64 Loughman, B.C.; Ratcliffe, R.G. 1984. Nuclear magnetic resonance and the study of plants. Pages 242-283 in P.B. Tinker, and A. Läuchli, editors. *Advances in Plant Nutrition*, Vol. 1. New York, Praeger Publishers.
- 65 Martin, F. 1985. Monitoring plant metabolism by ^{13}C , ^{15}N and ^{14}N nuclear magnetic resonance spectroscopy. A review of the applications to algae, fungi and higher plants. *Physiol. Vég.* 23:463-490.
- 66 Ratcliffe, R.G. 1987. Application of nuclear magnetic resonance methods to plant tissues. *Meth. Enzym.* 148:683-700.
- 67 Roberts, J.K.M. 1984. Study of plant metabolism *in vivo* using NMR spectroscopy. *Ann. Rev. Plant Physiol.* 35:375-386.
- 68 Simpson, T.J. 1986. ^{13}C -NMR in metabolic studies. Pages 1-42 in H.F. Linskens, and J.F. Jackson, editors. *Modern Methods of Plant Analysis Series*, Vol. 2, Nuclear Magnetic Resonance. Berlin, Springer-Verlag. 215 p.

IV. Bacteria

IV (a). Energetics

- 69 Koyama, Y.; Tahara, M.; Akutsu, H.; Kyogoku, Y. 1984. Light-induced pH change inside the chromatophores of *Rhodospseudomonas spheroides* G1C as revealed by ^{31}P -NMR. *Photobiochem. Photobiophys.* 7:163-174.
- 70 Nicolay, K.; Kaptein, R.; Hellingwerf, K.J.; Konings, W.N. 1981. ^{31}P nuclear magnetic resonance studies of energy transduction in *Rhodospseudomonas sphaeroides*. *Eur. J. Biochem.* 116:191-197.

-
- 71 Nicolay, K.; Lolkema, J.; Hellingwerf, K.J.; Kaptein, R.; Konings, W.N. 1981. Quantitative agreement between the values for the light-induced ΔpH in *Rhodospseudomonas sphaeroides* measured with automated flow-dialysis and ^{31}P NMR. Fed. Eur. Biochem. Soc. Lett. 123:319-323.

IV (b). Biosynthesis and Metabolism

- 72 Ashworth, D.J.; Chen, C.S.; Mascarenhas, D. 1986. Direct observation of tryptophan biosynthesis in *Escherichia coli* by carbon-13 nuclear magnetic resonance spectroscopy. Anal. Chem. 58:526-532.
- 73 Choi, B.-S.; Roberts, M.F. 1987. ^{15}N -NMR studies of *Methanobacterium thermoautotrophicum*: comparison of assimilation of different nitrogen sources. Biochim. Biophys. Acta 928:259-265.
- 74 Ekiel, I.; Smith, I.C.P.; Sprott, G.D. 1983. Biosynthetic pathways in *Methanospirillum hungatei* as determined by ^{13}C nuclear magnetic resonance. J. Bacteriol. 156:316-326.
- 75 Evans, J.N.S.; Raleigh, D.P.; Tolman, C.J.; Roberts, M.F. 1986. ^{13}C NMR spectroscopy of *Methanobacterium thermoautotrophicum*, carbon fluxes and primary metabolic pathways. J. Biol. Chem. 261:16323-16331.
- 76 Evans, J.N.S.; Tolman, C.J.; Kanodia, S.; Roberts, M.F. 1985. 2,3-cyclopyrophosphoglycerate in methanogens: evidence by ^{13}C NMR spectroscopy for a role in carbohydrate metabolism. Biochemistry 24:5693-5698.
- 77 Hunter, B.K.; Nicholls, K.M.; Sanders, J.K.M. 1984. Formaldehyde metabolism by *Escherichia coli*. In vivo carbon, deuterium, and two-dimensional NMR observations of multiple detoxifying pathways. Biochemistry 23:508-514.
- 78 Imai, Y.; Morita, S.; Arata, Y. 1984. Proton correlation NMR studies of metabolism in *Rhodospseudomonas palustris*. J. Biochem. 96:691-699.
- 79 Ogino, T.; Arata, Y.; Fujiwara, S. 1980. Proton correlation nuclear magnetic resonance study of metabolic regulations and pyruvate transport in anaerobic *Escherichia coli* cells. Biochem. 19:3684-3691.
- 80 Ogino, T.; Garner, C.; Markley, J.L.; Herrmann, K.M. 1982. Biosynthesis of aromatic compounds: ^{13}C NMR spectroscopy of whole *Escherichia coli* cells. Proc. Natl. Acad. Sci. USA 79:5828-5832.
- 81 Santos, H.; Fareleira, P.; Toci, R.; LeGall, J.; Peck, H.D. Jr.; Xavier, A.V. 1989. In vivo ^{31}P - and ^{13}C -NMR studies of ATP synthesis and methane formation by *Methanosarcina barkeri*. Eur. J. Biochem. 180:421-427.
- 82 Seely, R.J.; Fahrney, D.E. 1983. A novel diphospho-P,P'-diester from *Methanobacterium thermoautotrophicum*. J. Biol. Chem. 258:10835-10838.
- 83 Tel-Or, E.; Spath, S.; Packer, L.; Mehlhorn, R.J. 1986. Carbon-13 NMR studies of salt shock-induced carbohydrate turnover in the marine cyanobacterium *Agmenellum quadruplicatum*. Plant Physiol. 82:646-652.
- 84 Unkefer, C.J.; London, R.E. 1984. In vivo studies of pyridine nucleotide metabolism in *Escherichia coli* and *Saccharomyces cerevisiae* by carbon-13 NMR spectroscopy. J. Biol. Chem. 259:2311-2320.
- 85 Vink, R.; Bendall, M.R.; Simpson, S.J.; Rogers, P.J. 1984. Estimation of H^+ to adenosine 5'-triphosphate stoichiometry of *Escherichia coli* ATP synthase using ^{31}P NMR. Biochemistry 23:3667-3675.
-

-
- 86 Walker, T.E.; Han, C.H.; Kollman, V.H.; London, R.E.; Matwiyoff, N.A. 1982. ^{13}C nuclear magnetic resonance studies of the biosynthesis by *Microbacterium ammoniaphilum* of L-glutamate selectively enriched with carbon-13. *J. Biol. Chem.* 257:1189-1195.

IV (c). Structural Studies

- 87 Bowers, J.L.; Oldfield, E. 1988. Quantitative carbon-13 nuclear magnetic resonance spectroscopic study of mobile residues in bacteriorhodopsin. *Biochemistry* 27:5156-5161.
- 88 Jacob, G.S.; Garbow, J.R.; Schaefer, J. 1986. Direct measurement of poly(8-hydroxybutyrate) in a pseudomonad by solid-state ^{13}C NMR. *J. Biol. Chem.* 261:16785-16787.
- 89 Lundin, R.E.; Sacks, L.E. 1988. High-resolution solid-state ^{13}C nuclear magnetic resonance of bacterial spores: identification of the alpha-carbon signal of dipicolinic acid. *Appl. Env. Microbiol.* 54:923-928.
- 90 Nichol, C.P.; Davis, J.H.; Weeks, G.; Bloom, M. 1980. Quantitative study of the fluidity of *Escherichia coli* membranes using deuterium magnetic resonance. *Biochemistry* 19:451-457.
- 91 Smith, S.O.; de Groot, H.J.M.; Gebhard, R.; Courtin, J.M.L.; Lugtenburg, J.; Herzfeld, J.; Griffin, R.G. 1989. Structure and protein environment of the retinal chromophore in light- and dark-adapted bacteriorhodopsin studied by solid-state NMR. *Biochemistry* 28:8897-8904.

V. Fungi

V (a). Ectomycorrhizae

- 92 Boudot, D.; Canet, D.; Brondeau, J.; Martin, F. 1988. Quantitation and identification of carbon-13 isotopomers by homonuclear polarization transfer NMR experiments. *Fed. Eur. Biochem. Soc. Lett.* 231:11-15.
- 93 Martin, F. 1985. ^{15}N -NMR studies of nitrogen assimilation and amino acid biosynthesis in the ectomycorrhizal fungus *Cenococcum graniforme*. *Fed. Eur. Biochem. Soc. Lett.* 182:350-354.
- 94 Martin, F.; Canet, D. 1986. Biosynthesis of amino acids during [^{13}C]glucose utilization by the ectomycorrhizal ascomycete *Cenococcum geophilum* monitored by ^{13}C nuclear magnetic resonance. *Physiol. Vég.* 24:209-218.
- 95 Martin, F.; Canet, D.; Marchal, J.-P. 1984. *In vivo* natural abundance ^{13}C NMR studies of the carbohydrate storage in ectomycorrhizal fungi. *Physiol. Vég.* 22:733-743.
- 96 Martin, F.; Canet, D.; Marchal, J.-P. 1985. ^{13}C nuclear magnetic resonance study of mannitol cycle and trehalose synthesis during glucose utilization by the ectomycorrhizal ascomycete *Cenococcum graniforme*. *Plant Physiol.* 77:499-502.
- 97 Martin, F.; Canet, D.; Marchal, J.-P.; Brondeau, J. 1984. *In vivo* natural-abundance ^{13}C nuclear magnetic resonance studies of living ectomycorrhizal fungi, observation of fatty acids in *Cenococcum graniforme* and *Hebeloma crustuliniforme*. *Plant Physiol.* 75:151-153.
- 98 Martin, F.; Canet, D.; Rolin, D.; Marchal, J.-P.; Larher, F. 1983. Phosphorus-31 nuclear magnetic resonance study of polyphosphate metabolism in intact ectomycorrhizal fungi. *Plant Soil* 71:469-476.
-

- 99 Martin, F.; Marchal, J.-P.; Timinska, A.; Canet, D. 1985. The metabolism and physical state of polyphosphates in ectomycorrhizal fungi. A ^{31}P nuclear magnetic resonance study. *New Phytol.* 101:275-290.
- 100 Martin, F.; Ramstedt, M.; Söderhäll, K.; Canet, D. 1988. Carbohydrate and amino acid metabolism in the ectomycorrhizal ascomycete *Sphaerospora brunnea* during glucose utilization, a ^{13}C NMR study. *Plant Physiol.* 86:935-940.
- 101 Martin, F.; Stewart, G.R.; Genetet, I.; le Tacon, F. 1986. Assimilation of $^{15}\text{NH}_4^+$ by beech (*Fagus sylvatica* L.) ectomycorrhizas. *New Phytol.* 102:85-94.
- 102 Martin, F.; Stewart, G.R.; Genetet, I.; Mourot, B. 1988. The involvement of glutamate dehydrogenase and glutamine synthetase in ammonia assimilation by the rapidly growing ectomycorrhizal ascomycete, *Cenococcum geophilum* Fr. *New Phytol.* 110:541-550.

V (b). *Neurospora crassa*

- 103 Jacob, G.S.; Schaefer, J.; Stejskal, E.O.; McKay, R.A. 1980. Magic-angle N-15 NMR study of nitrate metabolism of *Neurospora crassa*. *Biochem. Biophys. Res. Comm.* 97:1176-1182.
- 104 Kanamori, K.; Legerton, T.L.; Weiss, R.L.; Roberts, J.D. 1982. Nitrogen-15 spin-lattice relaxation times of amino acids in *Neurospora crassa* as a probe of intracellular environment. *Biochemistry* 21:4916-4920.
- 105 Legerton, T.L.; Kanamori, K.; Weiss, R.L.; Roberts, J.D. 1981. ^{15}N NMR studies of nitrogen metabolism in intact mycelia of *Neurospora crassa*. *Proc. Natl. Acad. Sci. USA* 78:1495-1498.
- 106 Legerton, T.L.; Kanamori, K.; Weiss, R.L.; Roberts, J.D. 1983. Measurements of cytoplasmic and vacuolar pH in *Neurospora* using nitrogen-15 nuclear magnetic resonance spectroscopy. *Biochemistry* 22:899-903.

V (c). Other Fungi

- 107 Abell, C. 1986. The use of NMR spectroscopy to follow deuterium in studies of fungal metabolism. Pages 60-89 in H.F. Linskens, and J.F. Jackson, editors. *Modern Methods of Plant Analysis*, Vol. 2, Nuclear Magnetic Resonance. Berlin, Springer-Verlag. 215 p.
- 108 Dijkema, C.; Kester, H.C.M.; Visser, J. 1985. ^{13}C NMR studies of carbon metabolism in the hyphal fungus *Aspergillus nidulans*. *Proc. Natl. Acad. Sci. USA* 82:14-18.
- 109 Hocking, A.D.; Norton, R.S. 1983. Natural-abundance ^{13}C nuclear magnetic resonance studies on the internal solutes of xerophilic fungi. *J. Gen. Microbiol.* 129:2915-2925.
- 110 Jarvis, M.C. 1988. Direct observation of the structure of mycelial cell walls from the potato blight fungus *Phytophthora infestans* by solid-state ^{13}C NMR. *Lett. Appl. Microbiol.* 7:157-159.
- 111 Klein, G.; Cotter, D.A.; Martin, J.-B.; Bof, M.; Satre, M. 1988. Germination of *Dictyostelium discoideum* spores. A ^{31}P NMR analysis. *Biochemistry* 27:8199-8203.
- 112 Matsunaga, T.; Okubo, A.; Yamazaki, S.; Toda, S. 1980. Natural abundance ^{13}C nuclear magnetic resonance spectra of intact fungal mycelia. *Agric. Biol. Chem.* 44:2757-2759.

-
- 113 Yoshida, M.; Murai, T.; Moriya, S. 1984. ^{13}C NMR spectra of plant pathogenic fungi. *Agric. Biol. Chem.* 48:909-914.

V (d). Yeasts

- 114 Barton, J.K.; den Hollander, J.A.; Hopfield, J.J.; Shulman, R.G. 1982. ^{13}C nuclear magnetic resonance study of trehalose mobilization in yeast spores. *J. Bacteriol.* 151:177-185.
- 115 Campbell-Burk, S.L.; Shulman, R.G. 1987. High-resolution NMR studies of *Saccharomyces cerevisiae*. *Ann. Rev. Microbiol.* 41:595-616.
- 116 Juretschke, H.P. 1984. Double-quantum ^1H NMR studies of nitrogen metabolism in yeast. *Fed. Eur. Biochem. Soc. Lett.* 178:123-126.
- 117 Lohmeier-Vogel, E.; Skoog, K.; Vogel, H.; Hahn-Hägerdal, B. 1989. ^{31}P nuclear magnetic resonance study of the effect of azide on xylose fermentation by *Candida tropicalis*. *Appl. Environ. Microbiol.* 55:1974-1980.
- 118 Navon, G.; Shulman, R.G.; Yamane, T.; Eccleshall, T.R.; Lam, K.-B.; Baronofsky, J.J.; Marmur, J. 1979. Phosphorus-31 nuclear magnetic resonance studies of wild-type and glycolytic pathway mutants of *Saccharomyces cerevisiae*. *Biochemistry* 18:4487-4499.
- 119 Nicolay, K.; Scheffers, W.A.; Bruinenberg, P.M.; Kaptein, R. 1982. Phosphorus-31 nuclear magnetic resonance studies of intracellular pH, phosphate compartmentation and phosphate transport in yeasts. *Arch. Microbiol.* 133:83-89.
- 120 Nicolay, K.; Scheffers, W.A.; Bruinenberg, P.M.; Kaptein, R. 1983. *In vivo* ^{31}P NMR studies on the role of the vacuole in phosphate metabolism in yeasts. *Arch. Microbiol.* 134:270-275.
- 121 Sillerud, L.O.; Alger, J.R.; Shulman, R.G. 1981. High-resolution proton NMR studies of intracellular metabolites in yeast using ^{13}C decoupling. *J. Mag. Res.* 45:142-150.
- 122 Thevelein, J.M.; den Hollander, J.A.; Shulman, R.G. 1982. Changes in the activity and properties of trehalase during early germination of yeast ascospores: correlation with trehalose breakdown as studied by *in vivo* ^{13}C NMR. *Proc. Natl. Acad. Sci. USA* 79:3503-3507.
- 123 Tijssen, J.P.F.; van Steveninck, J. 1984. Detection of a yeast polyphosphate fraction localized outside the plasma membrane by the method of phosphorus-31 nuclear magnetic resonance. *Biochem. Biophys. Res. Comm.* 119:447-451.

VI. Algae and Higher Plants

VI (a). NMR Techniques for *in vivo* Plant Studies

- 124 Fox, G.G.; Ratcliffe, R.G.; Southon, T.E. 1989. Airlift systems for *in vivo* NMR spectroscopy of plant tissues. *J. Mag. Res.* 82:360-366.
- 125 Kime, M.J.; Ratcliffe, R.G.; Loughman, B.C. 1982. The application of ^{31}P nuclear magnetic resonance to higher plant tissue. II. Detection of intracellular changes. *J. Exp. Bot.* 33:670-681.

-
- 126 Kime, M.J.; Ratcliffe, R.G.; Williams, R.J.P.; Loughman, B.C. 1982. The application of ^{31}P nuclear magnetic resonance to higher plant tissue. I. Detection of spectra. *J. Exp. Bot.* 33:656-669.
- 127 Lee, R.B.; Ratcliffe, R.G. 1983. Development of an aeration system for use in plant tissue NMR experiments. *J. Exp. Bot.* 34:1213-1221.
- 128 Mitsumori, F.; Yoneyama, T.; Ito, O. 1985. Phosphorus-31 nuclear magnetic resonance studies on higher plant tissue. *Plant Sci.* 38:87-92.
- 129 Ratcliffe, R.G. 1986. NMR and the inorganic composition of plants. *J. Inorg. Biochem.* 28:347-354.
- 130 Roberts, J.K.M.; Testa, M.P. 1988. ^{31}P -NMR spectroscopy of roots of intact corn seedlings. *Plant Physiol.* 86:1127-1130.
- 131 Waterton, J.C.; Bridges, I.G.; Irving, M.P. 1983. Intracellular compartmentation detected by ^{31}P -NMR in intact photosynthetic wheat-leaf tissue. *Biochim. Biophys. Acta* 763:315-320.

VI (b). Carbon Metabolism

- 132 Ashworth, D.J.; Lee, R.Y.; Adams, D.O. 1987. Characterization of acetate and pyruvate metabolism in suspension cultures of *Zea mays* by ^{13}C NMR spectroscopy. *Plant Physiol.* 85:463-468.
- 133 Borchert, R.; Everett, G.W. 1987. ^{13}C nuclear magnetic resonance study of acetate incorporation into malate during Ca^{2+} -uptake by isolated leaf tissues. *Plant Physiol.* 84:944-949.
- 134 Chang, K.; Roberts, J.K.M. 1989. Observation of cytoplasmic and vacuolar malate in maize root tips by ^{13}C -NMR spectroscopy. *Plant Physiol.* 89:197-203.
- 135 Dijkema, C.; de Vries, S.C.; Booi, H.; Schaafsma, T.J.; van Kammen, A. 1988. Substrate utilization by suspension cultures and somatic embryos of *Daucus carota* L. measured by ^{13}C NMR. *Plant Physiol.* 88:1332-1337.
- 136 Ito, O.; Mitsumori, F.; Totsuka, T. 1985. Effects of NO_2 and O_3 alone or in combination on kidney bean plants (*Phaseolus vulgaris* L.): products of $^{13}\text{CO}_2$ assimilation detected by ^{13}C nuclear magnetic resonance. *J. Exp. Bot.* 36:281-289.
- 137 Lines, C.E.M.; Ratcliffe, R.G.; Rees, T.A.V.; Southon, T.E. 1989. A ^{13}C NMR study of photosynthate transport and metabolism in the lichen *Xanthoria calcicola* Oxner. *New Phytol.* 111:447-456.
- 138 Mason, R.P.; Sanders, J.K.M.; Gidley, M.J. 1986. NMR visualization of free asparagine in potato tissue using adduct formation with $[^{13}\text{C}]$ formaldehyde. *Phytochemistry* 25:1567-1571.
- 139 Oh-Hama, T.; Seto, H.; Otake, N.; Miyachi, S. 1983. ^{13}C -NMR spectra of chlorophylls *a* and *b* in green algae biosynthetically enriched with $[1-^{13}\text{C}]$ glutamate. *Fed. Eur. Biochem. Soc. Lett.* 153:404-408.
- 140 Schaefer, J.; Kier, L.D.; Stejskal, E.O. 1980. Characterization of photorespiration in intact leaves using ^{13}C carbon dioxide labeling. *Plant Physiol.* 65:254-259.
- 141 Schaefer, J.; Stejskal, E.O.; Beard, C.F. 1975. Carbon-13 nuclear magnetic resonance analysis of metabolism in soybeans labeled by $^{13}\text{CO}_2$. *Plant Physiol.* 55:1048-1053.
- 142 Stidham, M.A.; Moreland, D.E.; Siedow, J.N. 1983. ^{13}C nuclear magnetic resonance studies of crassulacean acid metabolism in intact leaves of *Kalanchoe tubiflora*. *Plant Physiol.* 73:517-520.

VI (c). Nitrogen Metabolism

- 143 Ashworth, D.J.; Mettler, I.J. 1984. Direct observation of glycine metabolism in tobacco suspension cells by carbon-13 NMR spectroscopy. *Biochemistry* 23:2252-2257.
- 144 Belton, P.S.; Lee, R.B.; Ratcliffe, R.G. 1985. A ^{14}N nuclear magnetic resonance study of inorganic nitrogen metabolism in barley, maize and pea roots. *J. Exp. Bot.* 36:190-210.
- 145 Coker, G.T. III; Garbow, J.R.; Schaefer, J. 1987. ^{15}N and ^{13}C NMR determination of methionine metabolism in developing soybean cotyledons. *Plant Physiol.* 83:698-702.
- 146 Coker, G.T. III; Schaefer, J. 1985. ^{15}N and ^{13}C NMR determination of allantoin metabolism in developing soybean cotyledons. *Plant Physiol.* 77:129-135.
- 147 Martin, F.; Driss, M.B. 1986. ^{15}N nuclear magnetic resonance spectroscopy: a powerful tool to study amino acid biosynthesis in higher plants. Pages 191-195 in H. Lambers, J.J. Neeteson, and I. Stulen, editors. *Fundamental, ecological and agricultural aspects of nitrogen metabolism in higher plants*. Dordrecht, Martinus Hijhoff Publishers.
- 148 Monselise, E.B.-I.; Kost, D.; Porath, D.; Tal, M. 1987. ^{15}N nuclear magnetic resonance study of ammonium ion assimilation by *Lemna gibba* L. *New Phytol.* 107:341-345.
- 149 Neeman, M.; Aviv, D.; Degani, H.; Galun, E. 1985. Glucose and glycine metabolism in regenerating tobacco protoplasts, followed nondestructively by nuclear magnetic resonance spectroscopy. *Plant Physiol.* 77:374-378.
- 150 Schaefer, J.; Skokut, T.A.; Stejskal, E.O.; McKay, R.A.; Varner, J.E. 1981. Estimation of protein turnover in soybean leaves using magic angle double cross-polarization nitrogen-15 nuclear magnetic resonance. *J. Biol. Chem.* 256:11574-11579.
- 151 Schaefer, J.; Skokut, T.A.; Stejskal, E.O.; McKay, R.A.; Varner, J.E. 1981. Asparagine amide metabolism in developing cotyledons of soybean. *Proc. Natl. Acad. Sci. USA* 78:5978-5982.
- 152 Schaefer, J.; Stejskal, E.O.; Garbow, J.R.; McKay, R.A. 1984. Quantitative determination of the concentrations of ^{13}C - ^{15}N chemical bonds by double cross-polarization NMR. *J. Mag. Res.* 59:150-156.
- 153 Schaefer, J.; Stejskal, E.O.; McKay, R.A. 1979. Cross-polarization NMR of N-15 labeled soybeans. *Biochem. Biophys. Res. Comm.* 88:274-280.
- 154 Skokut, T.A.; Varner, J.E.; Schaefer, J.; Stejskal, E.O.; McKay, R.A. 1982. [^{15}N]NMR determination of asparagine and glutamine nitrogen utilization for synthesis of storage protein in developing cotyledons of soybean in culture. *Plant Physiol.* 69:308-313.
- 155 Skokut, T.A.; Varner, J.E.; Schaefer, J.; Stejskal, E.O.; McKay, R.A. 1982. ^{15}N - and [^{13}C]NMR determination of utilization of glycine for synthesis of storage protein in the presence of glutamine in developing cotyledons of soybean. *Plant Physiol.* 69:314-316.
- 156 Thorpe, T.A.; Bagh, K.; Cutler, A.J.; Dunstan, D.I.; McIntyre, D.D.; Vogel, H.J. 1989. A ^{14}N and ^{15}N nuclear magnetic resonance study of nitrogen metabolism in shoot-forming cultures of white spruce (*Picea glauca*) buds. *Plant Physiol.* 91:193-202.

VI (d). Energetics and Phosphorus Metabolism

- 157 Brodelius, P. and Vogel, H.J. 1985. A phosphorus-31 nuclear magnetic resonance study of phosphate uptake and storage in cultured *Catharanthus roseus* and *Daucus carota* plant cells. *J. Biol. Chem.* 260:3556-3560.
- 158 Elgavish, A.; Elgavish, G.A. 1980. ³¹P-NMR differentiation between intracellular phosphate pools in *Cosmarium* (chlorophyta). *J. Phycol.* 16:368-374.
- 159 Elgavish, A.; Elgavish, G.A.; Halmann, M.; Berman, T.; Shomer, I. 1980. Intracellular phosphorus pools in intact algal cells, ³¹P NMR and transmission electron microscopy studies. *Fed. Eur. Biochem. Soc. Lett.* 117:137-142.
- 160 Hooks, M.A.; Clark, R.A.; Nieman, R.H.; Roberts, J.K.M. 1989. Compartmentation of nucleotides in corn root tips studied by ³¹P-NMR and HPLC. *Plant Physiol.* 89:963-969.
- 161 Jackson, P.C.; Pfeffer, P.E.; Gerasimowicz, W.V. 1986. Use of ³¹P NMR to assess effects of DNP on ATP levels *in vivo* in barley roots. *Plant Physiol.* 81:1130-1133.
- 162 Lauer, M.J.; Blevins, D.G.; Sierzputowska-Gracz, H. 1989. ³¹P-nuclear magnetic resonance determination of phosphate compartmentation in leaves of reproductive soybeans (*Glycine max* L.) as affected by phosphate nutrition. *Plant Physiol.* 89:1331-1336.
- 163 Lee, R.B.; Ratcliffe, R.G. 1983. Phosphorus nutrition and the intracellular distribution of inorganic phosphate in pea root tips: a quantitative study using ³¹P-NMR. *J. Exp. Bot.* 34:1222-1244.
- 164 Lohmeier-Vogel, E.M.; Hahn-Hägerdahl, B.; Vogel, H.J. 1986. Phosphorus-31 NMR studies of maltose and glucose metabolism in *Streptococcus lactis*. *Appl. Microbiol. Biotechnol.* 25:43-51.
- 165 Loughman, B.C.; Ratcliffe, R.G.; Schwabe, J.W.R. 1989. Galactose metabolism in *Zea mays* root tissues observed by ³¹P-NMR spectroscopy. *Plant Science* 59:11-23.
- 166 Loughman, B.C.; Ratcliffe, R.G.; Southon, T.E. 1989. Observations on the cytoplasmic and vacuolar orthophosphate pools in leaf tissues using *in vivo* ³¹P-NMR spectroscopy. *Fed. Eur. Biochem. Soc. Lett.* 242:279-284.
- 167 Lundberg, P.; Linsefors, L.; Vogel, H.J.; Brodelius, P. 1986. Permabilization of plant cells: ³¹P NMR studies on the permeability of the tonoplast. *Plant Cell Reports* 5:13-16.
- 168 Lundberg, P.; Weich, R.G.; Jensen, P.; Vogel, H.J. 1989. Phosphorus-31 and nitrogen-14 NMR studies of the uptake of phosphorus and nitrogen compounds in the marine macroalgae *Ulva lactuca*. *Plant Physiol.* 89:1380-1387.
- 169 Mitsumori, F.; Ito, O. 1984. Phosphorus-31 nuclear magnetic resonance studies of photosynthesizing *Chlorella*. *Fed. Eur. Biochem. Soc. Lett.* 174:248-252.
- 170 Rébeillé, F.; Bligny, R.; Martin, J.-B.; Douce, R. 1985. Effect of sucrose starvation on sycamore (*Acer pseudoplatanus*) cell carbohydrate and P_i status. *Biochem. J.* 226:679-684.
- 171 Roberts, J.K.M. 1986. Determination of the energy status of plant cells by ³¹P-nuclear magnetic resonance spectroscopy. Pages 43-59 in H.F. Linskens, and J.F. Jackson, editors. *Modern Methods of Plant Analysis Series, Vol. 2, Nuclear Magnetic Resonance*. Berlin, Springer-Verlag. 215 p.

-
- 172 Roberts, J.K.M.; Lane, A.N.; Clark, R.A.; Nieman, R.H. 1985. Relationships between the rate of synthesis of ATP and the concentrations of reactants and products of ATP hydrolysis in maize root tips, determined by ^{31}P nuclear magnetic resonance. *Arch. Biochem. Biophys.* 240:712-722.
- 173 Roberts, J.K.M.; Wemmer, D.; Jardetzky, O. 1984. Measurement of mitochondrial ATPase activity in maize root tips by saturation transfer ^{31}P nuclear magnetic resonance. *Plant Physiol.* 74:632-639.
- 174 Robins, R.J.; Ratcliffe, R.G. 1984. Intracellular distribution of phosphate in cultured *Humulus lupulus* cells growing at elevated exogenous phosphate concentrations. *Plant Cell Reports* 3:234-236.
- 175 Roby, C.; Martin, J.-B.; Bligny, R.; Douce, R. 1987. Biochemical changes during sucrose deprivation in higher plant cells, phosphorus-31 nuclear magnetic resonance studies. *J. Biol. Chem.* 262:5000-5007.
- 176 Rolin, D.B.; Boswell, R.T.; Sloger, C.; Tu, S.-I.; Pfeffer, P.E. 1989. *In vivo* ^{31}P NMR spectroscopic studies of soybean *Bradyrhizobium* symbiosis. I. Optimization of parameters. *Plant Physiol.* 89:1238-1246.
- 177 Ruyters, G.; Oh-hama, T.; Kowallik, W. 1985. Phosphate compounds of *Scenedesmus* C-2A' in darkness or blue light as measured by ^{31}P NMR. *Plant Cell Physiol.* 26:571-578.
- 178 Sianoudis, J.; Küsel, A.C.; Mayer, A.; Grimme, L.H.; Leibfritz, D. 1986. Distribution of polyphosphates in cell-compartments of *Chlorella fusca* as measured by ^{31}P -NMR-spectroscopy. *Arch. Microbiol.* 144:48-54.
- 179 Vogel, H.J. 1987. NMR studies of phosphate uptake and storage in plant cells and algae. *Ann. N. Y. Acad. Sci.* 508:164-175.
- 180 Vogel, H.J.; Brodelius, P. 1984. An *in vivo* ^{31}P NMR comparison of freely suspended and immobilized *Catharanthus roseus* plant cells. *J. Biotechnol.* 1:159-170.
- 181 Yazaki, Y.; Asukagawa, N.; Ishikawa, Y.; Ohta, E.; Sakata, M. 1988. Estimation of cytoplasmic free Mg^{2+} levels and phosphorylation potentials in mung bean root tips by *in vivo* ^{31}P NMR spectroscopy. *Plant Cell Physiol.* 29:919-924.

VI (e). pH Measurement and Regulation

- 182 Enami, I.; Akutsu, H.; Kyogoku, Y. 1986. Intracellular pH regulation in an acidophilic unicellular alga, *Cyanidium caldarium*: ^{31}P -NMR determination of intracellular pH. *Plant Cell Physiol.* 27:1351-1359.
- 183 Gimmler, H.; Kugel, H.; Leibfritz, D.; Mayer, A. 1988. Cytoplasmic pH of *Dunaliella parva* and *Dunaliella acidophila* as monitored by *in vivo* ^{31}P -NMR spectroscopy and the DMO method. *Physiol. Plant.* 74:521-530.
- 184 Guern, J.; Mathieu, Y.; Kurkdjian, A.; Manigault, P.; Manigault, J.; Gillet, B.; Beloeil, J.-C.; Lallemand, J.-Y. 1989. Regulation of vacuolar pH of plant cells. II. A ^{31}P NMR study of the modifications of vacuolar pH in isolated vacuoles induced by proton pumping and cation/ H^+ exchanges. *Plant Physiol.* 89:27-36.
- 185 Guern, J.; Mathieu, Y.; Pean, M.; Pasquier, C.; Beloeil, J.-C.; Lallemand, J.-Y. 1986. Cytoplasmic pH regulation in *Acer pseudoplatanus* cells. I. A ^{31}P NMR description of acid-load effects. *Plant Physiol.* 82:840-845.

-
- 186 Kuchitsu, K.; Oh-hama, T.; Tsuzuki, M.; Miyachi, S. 1987. Detection and characterization of acidic compartments (vacuoles) in *Chlorella vulgaris* 11h cells by ^{31}P -*in vivo* NMR spectroscopy and cytochemical techniques. Arch. Microbiol. 148:83-87.
- 187 Kurkdjian, A.; Guern, J. 1989. Intracellular pH: measurement and importance in cell activity. Ann. Rev. Plant Physiol. Plant Mol. Biol. 40:271-303.
- 188 Martin, J.-B.; Bligny, R.; Rebeille, F.; Douce, R.; Leguay, J.-J.; Mathieu, Y.; Guern, J. 1982. A ^{31}P nuclear magnetic resonance study of intracellular pH of plant cells cultivated in liquid medium. Plant Physiol. 70:1156-1161.
- 189 Martin, J.-B.; Foray, M.-F.; Klein, G.; Satre, M. 1987. Identification of inositol hexaphosphate in ^{31}P -NMR spectra of *Dictyostelium discoideum* amoebae. Relevance to intracellular pH determination. Biochim. Biophys. Acta 931:16-25.
- 190 Mathieu, Y.; Guern, J.; Kurkdjian, A.; Manigault, P.; Manigault, J.; Zielinska, T.; Gillet, B.; Beloeil, J.-C.; Lallemand, J.-Y. 1989. Regulation of vacuolar pH of plant cells. I. Isolation and properties of vacuoles suitable for ^{31}P NMR studies. Plant Physiol. 89:19-26.
- 191 Mimura, T.; Kirino, Y. 1984. Changes in cytoplasmic pH measured by ^{31}P -NMR in cells of *Nitellopsis obtusa*. Plant Cell Physiol. 25:813-820.
- 192 Ohmori, M.; Oh-hama, T.; Furihata, K.; Miyachi, S. 1986. Effect of ammonia on cellular pH of *Anabaena cylindrica* determined with ^{31}P NMR spectroscopy. Plant Cell Physiol. 27:563-566.
- 193 Reid, R.J.; Field, L.D.; Pitman, M.G. 1985. Effects of external pH, fusicoccin and butyrate on the cytoplasmic pH in barley root tips measured by ^{31}P -nuclear magnetic resonance spectroscopy. Planta 166:341-347.
- 194 Reid, R.J.; Loughman, B.C.; Ratcliffe, R.G. 1985. ^{31}P NMR measurements of cytoplasmic pH changes in maize root tips. J. Exp. Bot. 36:889-897.
- 195 Roberts, J.K.M. 1986. NMR methods for determination of intracellular pH. Pages 106-126 in H.F. Linskens, and J.F. Jackson, editors. Modern Methods of Plant Analysis Series, Vol. 2, Nuclear Magnetic Resonance. Berlin, Springer-Verlag. 215 p.
- 196 Roberts, J.K.M.; Ray, P.M.; Wade-Jardetzky, N.; Jardetzky, O. 1980. Estimation of cytoplasmic and vacuolar pH in higher plant cells by ^{31}P NMR. Nature 283:870-872.
- 197 Roberts, J.K.M.; Ray, P.M.; Wade-Jardetzky, N.; Jardetzky, O. 1981. Extent of intracellular pH changes during H^+ extrusion by maize root-tip cells. Planta 152:74-78.
- 198 Roberts, J.K.M.; Wade-Jardetzky, N.; Jardetzky, O. 1981. Intracellular pH measurements by ^{31}P nuclear magnetic resonance. Influence of factors other than pH on ^{31}P chemical shifts. Biochemistry 20:5389-5394.
- 199 Roberts, J.K.M.; Wemmer, D.; Ray, P.M.; Jardetzky, O. 1982. Regulation of cytoplasmic and vacuolar pH in maize root tips under different experimental conditions. Plant Physiol. 69:1344-1347.
- 200 Sianoudis, J.; Küsel, A.C.; Mayer, A.; Grimme, L.H.; Leibfritz, D. 1987. The cytoplasmic pH in photosynthesizing cells of the green alga *Chlorella fusca*, measured by ^{31}P NMR spectroscopy. Arch. Microbiol. 147:25-29.
-

-
- 201 Torimitsu, K.; Yazaki, Y.; Nagasuka, K.; Ohta, E.; Sakata, M. 1984. Effect of external pH on the cytoplasmic and vacuolar pHs in mung bean root-tip cells: a ^{31}P nuclear magnetic resonance study. *Plant Cell Physiol.* 25:1403-1409.
- 202 Wray, V.; Schiel, O.; Berlin, J.; Witte, L. 1985. Phosphorus-31 nuclear magnetic resonance investigation of the *in vivo* regulation of intracellular pH in cell suspension cultures of *Nicotiana tabacum*: the effects of oxygen supply, nitrogen, and external pH change. *Arch. Biochem. Biophys.* 236:731-740.

VI (f). Osmotic Regulation and Cation Transport

- 203 Balschi, J.A.; Cirillo, V.P.; Springer, C.S. Jr. 1982. Direct high-resolution nuclear magnetic resonance studies of cation transport *in vivo*, Na^+ transport in yeast cells. *Biophys. J.* 38:323-326.
- 204 Ben-Hayyim, G.; Navon, G. 1985. Phosphorus-31 NMR studies of wild-type and NaCl-tolerant *Citrus* cultured cells. *J. Exp. Bot.* 36:1877-1888.
- 205 Bental, M.; Degani, H.; Avron, M. 1988. ^{23}Na -NMR studies of the intracellular sodium ion concentration in the halotolerant alga *Dunaliella salina*. *Plant Physiol.* 87:813-817.
- 206 Bental, M.; Oren-Shamir, M.; Avron, M.; Degani, H. 1988. ^{31}P and ^{13}C -NMR studies of the phosphorus and carbon metabolites in the halotolerant alga, *Dunaliella salina*. *Plant Physiol.* 87:320-324.
- 207 Bienfait, H.F.; Lubberding, H.J.; Heutink, P.; Lindner, L.; Visser, J.; Kaptein, R.; Dijkstra, K. 1989. Rhizosphere acidification by iron deficient bean plants: the role of trace amounts of divalent metal ions, a study on roots of intact plants with the use of ^{11}C - and ^{31}P -NMR. *Plant Physiol.* 90:359-364.
- 208 Castle, A.M.; Macnab, R.M.; Shulman, R.G. 1986. Measurement of intracellular sodium concentration and sodium transport in *Escherichia coli* by ^{23}Na nuclear magnetic resonance. *J. Biol. Chem.* 261:3288-3294.
- 209 Castle, A.M.; Macnab, R.M.; Shulman, R.G. 1986. Coupling between the sodium and proton gradients in respiring *Escherichia coli* cells measured by ^{23}Na and ^{31}P nuclear magnetic resonance. *J. Biol. Chem.* 261:7797-7806.
- 210 Gerasimowicz, W.V.; Tu, S.-I.; Pfeffer, P.E. 1986. Energy facilitated Na^+ uptake in excised corn roots via ^{31}P and ^{23}Na NMR. *Plant Physiol.* 81:925-928.
- 211 Ginzburg, M.; Ratcliffe, R.G.; Southon, T.E. 1988. Phosphorus metabolism and intracellular pH in the halotolerant alga *Dunaliella parva* studied by ^{31}P -NMR. *Biochim. Biophys. Acta* 969:225-235.
- 212 Gupta, R.K.; Gupta, P. 1982. Direct observation of resolved resonances from intra- and extracellular sodium-23 ions in NMR studies of intact cells and tissues using dysprosium(III)tripolyphosphate as paramagnetic shift reagent. *J. Mag. Res.* 47:344-350.
- 213 Kuchitsu, K.; Katsuhara, M.; Miyachi, S. 1989. Rapid cytoplasmic alkalization and dynamics of intracellular compartmentation of inorganic phosphate during adaptation against salt stress in a halotolerant unicellular green alga *Dunaliella tertiolecta*: ^{31}P -nuclear magnetic resonance study. *Plant Cell Physiol.* 30:407-414.
- 214 Katsuhara, M.; Kuchitsu, K.; Takeshige, K.; Tazawa, M. 1989. Salt stress-induced cytoplasmic acidification and vacuolar alkalization in *Nitellopsis obtusa* cells, *in vivo* ^{31}P -nuclear magnetic resonance study. *Plant Physiol.* 90:1102-1107.

-
- 215 Larher, F. 1988. Natural abundance ^{13}C -nuclear magnetic resonance studies on the compatible solutes of halophytic higher plants. *Plant Physiol. Biochem.* 26:35-45.
- 216 Naidu, B.P.; Jones, G.P.; Paleg, L.G.; Poljakoff-Mayber, A. 1987. Proline analogues in *Melaleuca* species: response of *Melaleuca lanceolata* and *M. uncinata* to water stress and salinity. *Aust. J. Plant Physiol.* 14:669-677.
- 217 Norton, R.S.; MacKay, M.A.; Borowitzka, L.J. 1982. The physical state of osmoregulatory solutes in unicellular algae, a natural-abundance carbon-13 nuclear-magnetic-resonance relaxation study. *Biochem. J.* 202:699-706.
- 218 Pfeffer, P.E.; Tu, S.-I.; Gerasimowicz, W.V.; Cavanaugh, J.R. 1986. *In vivo* ^{31}P NMR studies of corn root tissue and its uptake of toxic metals. *Plant Physiol.* 80:77-84.
- 219 Poljakoff-Mayber, A.; Symon, D.E.; Jones, G.P.; Naidu, B.P.; Paleg, J. G. 1987. Nitrogenous compatible solutes in native South Australian plants. *Aust. J. Plant Physiol.* 14:341-350.
- 220 Roberts, J.K.M.; Linker, C.S.; Benoit, A.G.; Jardetzky, O.; Nieman, R.H. 1984. Salt stimulation of phosphate uptake in maize root tips studied by ^{31}P nuclear magnetic resonance. *Plant Physiol.* 75:947-950.
- 221 Robinson, S.P.; Jones, G.P. 1986. Accumulation of glycinebetaine in chloroplasts provides osmotic adjustment during salt stress. *Aust. J. Plant Physiol.* 13:659-668.
- 222 Sillerud, L.O.; Heyser, J.W. 1984. Use of ^{23}Na -nuclear magnetic resonance to follow sodium uptake and efflux in NaCl-adapted and nonadapted millet (*Panicum miliaceum*) suspensions. *Plant Physiol.* 75:269-272.
- 223 Weich, R.G.; Lundberg, P.; Vogel, H.J.; Jensen, P. 1989. Phosphorus-31 NMR studies of cell wall-associated calcium-phosphates in *Ulva lactuca*. *Plant Physiol.* 90:230-236.
- 224 Yazaki, Y.; Maki, K.; Sato, T.; Ohta, E.; Sakata, M. 1988. Application of ^{39}K NMR spectroscopy to potassium transport in mung bean root tips. *Plant Cell Physiol.* 29:1417-1422.

VI (g). Plant Hormones and Elicitors

- 225 Jones, G.P.; Marker, A.; Paleg, L.G. 1984. Complex formation between indole-3-acetic acid and phospholipid membrane components in aqueous media. 1. Parameters of the system. *Biochemistry* 23:1514-1520.
- 226 Jones, G.P.; Paleg, L.G. 1984. Complex formation between indole-3-acetic acid and phospholipid membrane components in aqueous media. 2. Interaction of auxins and related compounds with phosphatidylcholine membranes. *Biochemistry* 23:1521-1524.
- 227 Jones, G.P.; Paleg, L.G. 1984. Complex formation between indole-3-acetic acid and phospholipid membrane components in aqueous media. 3. Interaction of indole-3-acetic acid with amphiphiles containing the trimethylammonium group. *Biochemistry* 23:1525-1532.
- 228 Jones, G.P.; Paleg, L.G. 1988. Interaction of the plant hormone, indole-3-acetic acid, with phosphatidylcholine model membranes: effects of acyl chain length. *Biochim. Biophys. Acta* 945:175-184.
-

-
- 229 Jones, G.P.; Starr, R.K.; Paleg, L.G. 1985. Promotion of cation transport across phospholipid vesicular membranes by the plant hormone indole-3-acetic acid as studied by ^1H -NMR. *Biochim. Biophys. Acta* 812:77-83.
- 230 Misso, N.L.A.; Jones, G.P.; Paleg, L.G. 1986. Effects of phospholipid oxidation on the indole-3-acetic-acid-facilitated transport of Pr^{3+} ions into phosphatidylcholine vesicles. *Biochim. Biophys. Acta* 861:1-8.
- 231 Ojalvo, I.; Rokem, J.S.; Navon, G.; Goldberg, I. 1987. ^{31}P NMR study of elicitor treated *Phaseolus vulgaris* cell suspension cultures. *Plant Physiol.* 85:716-719.

VI (h). Seeds - Physiology and Chemical Analysis

- 232 Chen, S.; Eloffson, R.M.; MacTaggart, J.M. 1979. Carbon-13 nuclear magnetic resonance studies of lipids and starch digestion in intact seeds. *J. Agric. Food Chem.* 27:435-438.
- 233 Colnago, L.A.; Seidl, P.R. 1983. Application of carbon-13 nuclear magnetic resonance to the germination of soybean seeds *in vivo*. *J. Agric. Food Chem.* 31:459-461.
- 234 McCain, D.C. 1983. ^{31}P -NMR study of turnip seed germination and sprout growth inhibition by peroxodisulfate ion. *Biochim. Biophys. Acta* 763:231-236.
- 235 O'Donnell, D.J.; Ackerman, J.J.H.; Maciel, G.E. 1981. Comparative study of whole seed protein and starch content via cross polarization-magic angle spinning carbon-13 nuclear magnetic resonance spectroscopy. *J. Agric. Food Chem.* 29:514-518.
- 236 Ricardo, C.P.P.; Santos, H. 1990. Application of ^{31}P NMR to monitor phosphorus compounds and their changes during germination of legume seeds. *J. Exp. Bot.* 41:79-87.
- 237 Rutar, V. 1989. Magic angle sample spinning NMR spectroscopy of liquids as a nondestructive method for studies of plant seeds. *J. Agric. Food Chem.* 37:67-70.
- 238 Rutar, V.; Blinc, R. 1980. Nondestructive determination of protein content of viable seeds by proton enhanced ^{13}C NMR. *Z. Naturforsch.* 35c:12-15.
- 239 Rutar, V.; Kovač, M.; Lahajnar, G. 1988. Improved NMR spectra of liquid components in heterogeneous samples. *J. Mag. Res.* 80:133-138.
- 240 Rutar, V.; Kovač, M.; Lahajnar, G. 1989. Nondestructive study of liquids in single fir seeds using nuclear magnetic resonance and magic angle sample spinning. *J. Am. Oil Chem. Soc.* 66:961-965.
- 241 Schaefer, J.; Stejskal, E.O. 1974. Carbon-13 nuclear magnetic resonance measurement of oil composition in single viable soybeans. *J. Am. Oil Chem. Soc.* 51:210-213.
- 242 Schaefer, J.; Stejskal, E.O. 1975. Carbon-13 nuclear magnetic resonance analysis of intact oilseeds. *J. Am. Oil Chem. Soc.* 52:366-369.

VI (i). Pollen

- 243 Guilford, W.J.; Schneider, D.M.; Labovitz, J.; Opella, S.J. 1988. High resolution solid state ^{13}C NMR spectroscopy of sporopollenins from different plant taxa. *Plant Physiol.* 86:134-136.

-
- 244 Jackson, J.F.; Jones, G.; Linskens, H.F. 1982. Phytic acid in pollen. *Phytochemistry* 21:1255-1258.
- 245 Kerhoas, C.; Dumas, C. 1986. Nuclear magnetic resonance and pollen quality. Pages 169-190 in H.F. Linskens, and J.F. Jackson, editors. *Modern Methods of Plant Analysis Series*, Vol. 2, Nuclear Magnetic Resonance. Berlin, Springer-Verlag. 215 p.
- 246 Priestley, D.A.; de Kruijff, B. 1982. Phospholipid motional characteristics in a dry biological system, a ^{31}P -nuclear magnetic resonance study of hydrating *Typha latifolia* pollen. *Plant Physiol.* 70:1075-1078.

VI (j). Plant Cell Wall Polymers

- 247 Garbow, J.R.; Ferrantello, L.M.; Stark, R.E. 1989. ^{13}C nuclear magnetic resonance study of suberized potato cell wall. *Plant Physiol.* 90:783-787.
- 248 Irwin, P.L.; Pfeffer, P.E.; Gerasimowicz, W.V.; Pressey, R.; Sams, C.E. 1984. Ripening-related perturbations in apple cell wall nuclear spin dynamics. *Phytochemistry*. 23:2239-2242.
- 249 Irwin, P.L.; Gerasimowicz, W.V.; Pfeffer, P.E.; Fishman, M. 1985. ^1H - ^{13}C polarization transfer studies of uronic acid polymer systems. *J. Agric. Food Chem.* 33:1197-1201.
- 250 Jarvis, M.C.; Apperley, D.C. 1990. Direct observation of cell wall structure in living plant tissues by solid-state ^{13}C NMR spectroscopy. *Plant Physiol.* 92:61-65.
- 251 Joseleau, J.-P.; Chambat, G. 1984. ^{13}C N.M.R. spectroscopy to identify complex polysaccharide fractions from the plant cell wall. *Physiol. Vég.* 22:461-470.
- 252 Lewis, N.G.; Razal, R.A.; Yamamoto, E.; Bokelman, G.H.; Wooten, J.B. 1989. ^{13}C specific labeling of lignin in intact plants. Pages 169-181 in N.G. Lewis, and M.G. Paice, editors. *ACS Symposium Series*, Vol. 399, Plant Cell Wall Polymers, Biogenesis and Biodegradation. Washington, D.C., American Chemical Society. 676 p.
- 253 Lewis, N.G.; Yamamoto, E.; Wooten, J.B.; Just, G.; Ohashi, H.; Towers, G.H.N. 1987. Monitoring biosynthesis of wheat cell-wall phenylpropanoids *in situ*. *Science* 237:1344-1346.
- 254 MacKay, A.L.; Bloom, M.; Tepfer, M.; Taylor, I.E.P. 1982. Broadline proton magnetic resonance study of cellulose, pectin, and bean cell walls. *Biopolymers* 21:1521-1534.
- 255 MacKay, A.L.; Wallace, J.C.; Sasaki, K.; Taylor, I.E.P. 1988. Investigation of the physical structure of the primary plant cell wall by proton magnetic resonance. *Biochemistry* 27:1467-1473.
- 256 Manzi, A.E.; Cerezo, A.S.; Shoolery, J.N. 1986. High resolution ^{13}C -N.M.R. spectroscopy of legume-seed galactomannans. *Carbohydrate Res.* 148:189-197.
- 257 Nip, M.; de Leeuw, J.W.; Holloway, P.J.; Jensen, J.P.T.; Sprenkels, J.C.M.; de Pooter, M.; Sleenckx, J.J.M. 1987. Comparison of flash pyrolysis, differential scanning calorimetry, ^{13}C NMR and IR spectroscopy in the analysis of a highly aliphatic biopolymer from plant cuticles. *J. Anal. Appl. Pyrol.* 11:287-295.
- 258 Nip, M.; Tegelaar, E.W.; Brinkhuis, H.; de Leeuw, J.W.; Schenck, P.A.; Holloway, P.J. 1986. Analysis of modern and fossil plant cuticles by Curie point Py-GC and Curie point Py-GC-MS: recognition of a new, highly aliphatic and resistant biopolymer. *Org. Geochem.* 10:769-778.

-
- 259 Nip, M.; Tegelaar, E.W.; de Leeuw, J.W.; Schenck, P.A.; Holloway, P.J. 1986. A new non-saponifiable highly aliphatic and resistant biopolymer in plant cuticles: evidence from pyrolysis and ^{13}C -NMR analysis of present-day and fossil plants. *Naturwissenschaften* 73:579-585.
- 260 Pressey, R.; Himmelsbach, D.S. 1984. ^{13}C -N.m.r. spectrum of a D-galactose-rich polysaccharide from tomato fruit. *Carbohydrate Res.* 127:356-359.
- 261 Seewaldt, V.; Priestley, D.A.; Leopold, A.C.; Feigenson, G.W.; Goodsaid-Zalduondo, F. 1981. Membrane organization in soybean seeds during hydration. *Planta* 152:19-23.
- 262 Singh, J.; Blackwell, B.A.; Miller, R.W.; Bewley, J.D. 1984. Membrane organization of the desiccation-tolerant moss *Tortula ruralis* in dehydrated states. *Plant Physiol.* 75:1075-1079.
- 263 Stark, R.E.; Zlotnik-Mazori, T.; Ferrantello, L.M.; Garbow, J.R. 1989. Molecular structure and dynamics of intact plant polyesters, solid-state NMR studies. Pages 214-229 in N.G. Lewis, and M.G. Paice, editors. ACS Symposium Series, Vol. 399, Plant Cell Wall Polymers, Biogenesis and Biodegradation. Washington, D.C., American Chemical Society. 676 p.
- 264 Taylor, I.E.P.; Tepfer, M.; Callaghan, P.T.; MacKay, A.L.; Bloom, M. 1983. Use of ^1H NMR to study molecular motion in cellulose, pectin, and bean cell walls. *J. Appl. Polymer Sci.: Appl. Polymer Symp.* 37:377-384.
- 265 Wilson, M.A.; Sawyer, J.; Hatcher, P.G.; Lerch, H.E. III. 1989. 1,3,5-hydroxybenzene structures in mosses. *Phytochemistry* 28:1395-1400.
- 266 Zelibor, J.L. Jr.; Romankiw, L.; Hatcher, P.G.; Colwell, R.R. 1988. Comparative analysis of the chemical composition of mixed and pure cultures of green algae and their decomposed residues by ^{13}C nuclear magnetic resonance spectroscopy. *App. Env. Microbiol.* 54:1051-1060.
- 267 Zlotnik-Mazori, T.; Stark, R.E. 1988. Nuclear magnetic resonance studies of cutin, an insoluble plant polyester. *Macromolecules* 21:2412-2417.

VII. Water in Plants

VII (a). Analysis of Water Content

- 268 Chambers, J.; McKevitt, N.J.; Scudamore, K.A.; Bowman, C.E. 1989. Non-destructive determination of the moisture content of individual wheat grains by nuclear magnetic resonance. *J. Sci. Food Agric.* 49:211-224.
- 269 Hall, G.E.; Lawrence, J.G.; Simpson, R.J. 1967. Nuclear magnetic resonance as a method for continuously monitoring rehydration. *Nature* 216:474-475.
- 270 Miller, B.S.; Lee, M.S.; Hughes, J.W.; Pomeranz, Y. 1980. Measuring high moisture content of cereal grains by pulsed nuclear magnetic resonance. *Cereal Chem.* 57:126-129.
- 271 Morley, J.H.; Fletcher, P.D.; Morgan, A.G. 1984. The estimation of moisture in whole grain wheat and barley using nuclear magnetic resonance spectroscopy. *J. Nat. Inst. Agric. Bot. (GB)* 16:437-442.
-

VII (b). Physical State of Water in Plants

- 272 van As, H.; van Vliet, W.P.A.; Schaafsma, T.J. 1980. [^1H]spin-echo nuclear magnetic resonance in plant tissue. I. The effect of Mn(II) and water content in wheat leaves. *Biophys. J.* 32:1043-1050.
- 273 Bačić, G.; Božović, B.; Ratković, S. 1978. Proton magnetic relaxation in plant cells and tissues: effect of external ion concentration on spin-lattice relaxation time (T_1) and water content in primary roots of *Zea mays*. *Studia Biophysica* 70:31-43.
- 274 Bačić, G.; Ratković, S. 1984. Water exchange in plant tissue studied by proton NMR in the presence of paramagnetic centers. *Biophys. J.* 45:767-776.
- 275 Bačić, G.; Ratković, S. 1987. NMR studies of radial exchange and distribution of water in maize roots: the relevance of modelling of exchange kinetics. *J. Exp. Bot.* 38:1284-1297.
- 276 Belton, P.S.; Hills, B.P. 1987. The effects of diffusive exchange in heterogeneous systems on N.M.R. line shapes and relaxation processes. *Mol. Phys.* 61:999-1018.
- 277 Ratković, S.; Bačić, G.; Radenović, C.; Vučinić, Z. 1982. Water in plants: a review of some recent NMR studies concerning the state and transport of water in leaf, root and seed. *Studia Biophysica* 91:9-18.
- 278 Stout, D.G.; Cotts, R.M.; Steponkus, P.L. 1977. The diffusional water permeability of *Elodea* leaf cells as measured by nuclear magnetic resonance. *Can. J. Bot.* 55:1623-1631.
- 279 Stout, D.G.; Steponkus, P.L.; Bustard, L.D.; Cotts, R.M. 1978. Water permeability of *Chlorella* cell membranes by nuclear magnetic resonance, measured diffusion coefficients and relaxation times. *Plant Physiol.* 62:146-151.
- 280 Stout, D.G.; Steponkus, P.L.; Cotts, R.M. 1978. Nuclear magnetic resonance relaxation times and plasmalemma water exchange in ivy bark. *Plant Physiol.* 62:636-641.

VII (c). Cold Hardiness and Cryopreservation

- 281 Gusta, L.V.; Burke, M.J.; Kapoor, A.C. 1975. Determination of unfrozen water in winter cereals at subfreezing temperatures. *Plant Physiol.* 56:707-709.
- 282 Gusta, L.V.; Fowler, D.B.; Chen, P.; Russell, D.B.; Stout, D.G. 1979. A nuclear magnetic resonance study of water in cold-acclimating cereals. *Plant Physiol.* 63:627-634.
- 283 Kaku, S.; Iwaya-Inoue, M. 1987. Estimation of chilling sensitivity and injury in gloxinia leaves by the thermal hysteresis of NMR relaxation times of water protons. *Plant Cell Physiol.* 28:509-516.
- 284 Kaku, S.; Iwaya-Inoue, M. 1988. Monitoring primary response to chilling stress in etiolated *Vigna radiata* and *V. mungo* seedlings using thermal hysteresis of water proton NMR relaxation times. *Plant Cell Physiol.* 29:1063-1068.
- 285 Kaku, S.; Iwaya-Inoue, M.; Gusta, L.V. 1984. Relationship of nuclear magnetic resonance relaxation time to water content and cold hardiness in flower buds of evergreen azalea. *Plant Cell Physiol.* 25:875-882.
- 286 Kaku, S.; Iwaya-Inoue, M.; Gusta, L.V. 1985. Estimation of the freezing injury in flower buds of evergreen azaleas by water proton nuclear magnetic resonance relaxation times. *Plant Cell Physiol.* 26:1019-1025.

-
- 287 Morikawa, H.; Fukao, H.; Suzuki, E.; Nagashima, N.; Yamada, Y. 1988. Freezing behavior of intra- and extracellular water of cultured green cells of lavender as measured by NMR. *Agric. Biol. Chem.* 52:2085-2086.
- 288 Stout, D.G.; Steponkus, P.L.; Cotts, R.M. 1978. Plasmalemma alteration during cold acclimation of *Hedera helix* bark. *Can. J. Bot.* 56:196-205.
- 289 Tyler, N.; Stushnoff, C.; Gusta, L.V. 1988. Freezing of water in dormant vegetative apple buds in relation to cryopreservation. *Plant Physiol.* 87:201-205.

VII (d). Chloroplast Orientation

- 290 McCain, D.C. 1986. Orientation of chloroplasts in leaves by ^1H NMR spectroscopy. Pages 127-147 in H.F. Linskens, and J.F. Jackson, editors. *Modern Methods of Plant Analysis Series*, Vol. 2, Nuclear Magnetic Resonance. Berlin, Springer-Verlag. 215 p.
- 291 McCain, D.C.; Croxdale, J.; Markley, J.L. 1988. Water is allocated differently to chloroplasts in sun and shade leaves. *Plant Physiol.* 86:16-18.
- 292 McCain, D.C.; Markley, J.L. 1985. Water permeability of chloroplast envelope membranes, *in vivo* measurement by saturation-transfer NMR. *Fed. Eur. Biochem. Soc. Lett.* 183:353-358.
- 293 McCain, D.C.; Markley, J.L. 1985. A theory and a model for interpreting the proton nuclear magnetic resonance spectra of water in plant leaves. *Biophys. J.* 48:687-694.
- 294 McCain, D.C.; Markley, J.L. 1989. More manganese accumulates in maple sun leaves than in shade leaves. *Plant Physiol.* 90:1417-1421.
- 295 McCain, D.C.; Selig, T.C.; Govindjee; Markley, J.L. 1984. Some plant leaves have orientation-dependent EPR and NMR spectra. *Proc. Natl. Acad. Sci. USA* 81:748-752.

VII (e). Water Balance and Flow

- 296 van As, H.; Schaafsma, T.J. 1984. Noninvasive measurement of plant water flow by nuclear magnetic resonance. *Biophys. J.* 45:469-472.
- 297 de Jager, P.A.; Hemminga, M.A.; Sonneveld, A. 1978. Novel method for determination of flow velocities with pulsed nuclear magnetic resonance. *Rev. Sci. Instrum.* 49:1217-1218.
- 298 Hemminga, M.A.; de Jager, P.A. 1980. The study of flow by pulsed nuclear magnetic resonance. II. Measurement of flow velocities using a repetitive pulse method. *J. Mag. Res.* 37:1-16.
- 299 Hemminga, M.A.; de Jager, P.A.; Sonneveld, A. 1977. The study of flow by pulsed nuclear magnetic resonance. I. Measurement of flow rates in the presence of a stationary phase using a difference method. *J. Mag. Res.* 27:359-370.
- 300 Reinders, J.E.A.; van As, H.; Schaafsma, T.J.; de Jager, P.A.; Sheriff, D.W. 1988. Water balance in *Cucumis* plants, measured by nuclear magnetic resonance, I. *J. Exp. Bot.* 39:1199-1210.
- 301 Reinders, J.E.A.; van As, H.; Schaafsma, T.J.; Sheriff, D.W. 1988. Water balance in *Cucumis* plants, measured by nuclear magnetic resonance, II. *J. Exp. Bot.* 39:1211-1220.
-

VII (f). Imaging

- 302 Bottomley, P.A.; Rogers, H.H.; Foster, T.H. 1986. NMR imaging shows water distribution and transport in plant root systems *in situ*. Proc. Natl. Acad. Sci. USA 83:87-89.
- 303 Brown, D.P.; Bledsoe, C.; Ford, E.D.; Cothorn, J.S.; Perry, D. 1990. Development of an artificial soil medium for nuclear magnetic resonance imaging of Douglas-fir seedling roots. Submitted to Can. J. For. Res.
- 304 Brown, J.M.; Johnson, G.A.; Kramer, P.J. 1986. *In vivo* magnetic resonance microscopy of changing water content in *Pelargonium hortorum* roots. Plant Physiol. 82:1158-1160.
- 305 Connelly, A.; Lohman, J.A.B.; Loughman, B.C.; Quiquampoix, H.; Ratcliffe, R.G. 1987. High resolution imaging of plant tissues by NMR. J. Exp. Bot. 38:1713-1723.
- 306 German, J.B.; McCarthy, M.J. 1989. Stability of aqueous foams: analysis using magnetic resonance imaging. J. Agric. Food Chem. 37:1321-1324.
- 307 Listerud, J.M.; Sinton, S.W.; Drobny, G.P. 1989. NMR imaging of materials. Anal. Chem. 61:23A-35A.
- 308 Lohman, J.A.B.; Ratcliffe, R.G. 1988. Prospects for NMR imaging in the study of biological morphogenesis. Experientia 44:666-672.
- 309 Rogers, H.H.; Bottomley, P.A. 1987. *In situ* nuclear magnetic resonance imaging of roots: influence of soil type, ferromagnetic particle content, and soil water. Agron. J. 79:957-965.
- 310 Rollins, A.; Barber, J.; Elliott, R.; Wood, B. 1989. Xenobiotic monitoring in plants by ^{19}F and ^1H nuclear magnetic resonance imaging and spectroscopy, uptake of trifluoroacetic acid in *Lycopersicon esculentum*. Plant Physiol. 91:1243-1246.
- 311 Weisenberger, L.A.; Koenig, J.L. 1989. NMR imaging of solvent diffusion in polymers. Appl. Spectrosc. 43:1117-1126.

VIII. Invertebrates

VIII (a). Physiology

- 312 Asakura, T.; Kawaguchi, Y.; Demura, M.; Osanai, M. 1988. ^{13}C and ^{31}P NMR studies on sugar metabolism in *Bombyx mori* and *Philosamia cynthia ricini* larvae. Insect Biochem. 18:531-538.
- 313 Buchanan, G.W.; Storey, K.B. 1983. *In vivo* detection of cryoprotectants and lipids in overwintering larvae using carbon-13 nuclear magnetic resonance spectroscopy. Can. J. Biochem. Cell Biol. 61:1260-1264.
- 314 Chambers, J.; McKevitt, N.J.; Stubbs, M.R. 1984. Nuclear magnetic resonance spectroscopy for studying the development and detection of the grain weevil, *Sitophilus granarius* (L.) (Coleoptera: Curculionidae), within wheat kernels. Bull. Ent. Res. 74:707-724.
- 315 Chapman, A.; Linstead, D.J.; Lloyd, D.; Williams, J. 1985. ^{13}C -NMR reveals glycerol as an unexpected major metabolite of the protozoan parasite *Trichomonas vaginalis*. Fed. Eur. Biochem. Soc. Lett. 191:287-292.

-
- 316 Deslauriers, R.; Ekiel, I.; Byrd, R.A.; Jarrell, H.C.; Smith, I.C.P. 1982. A ^{31}P -NMR study of structural and functional aspects of phosphate and phosphonate distribution in *Tetrahymena*. *Biochim. Biophys. Acta* 720:329-337.
- 317 Deslauriers, R.; Jarrell, H.C.; Byrd, R.A.; Smith, I.C.P. 1980. Observation by ^{13}C NMR of metabolites in differentiating amoeba, trehalose storage in encysted *Acanthamoeba castellanii*. *Fed. Eur. Biochem. Soc. Lett.* 118:185-190.
- 318 Manville, J.F.; Sahota, T.S.; Hall, L.D.; Luck, S. 1988. *In vivo* pupal response to orientation detected by proton magnetic resonance chemical microscopy. *Comp. Biochem. Physiol.* 89A:449-454.
- 319 Martin, J.-B.; Klein, G.; Satre, M. 1987. ^{23}Na NMR study of intracellular sodium ions in *Dictyostelium discoideum* amoeba. *Arch. Biochem. Biophys.* 254:559-567.
- 320 Norton, R.S. 1979. Identification of mollusc metabolites by natural-abundance ^{13}C NMR studies of whole tissue and tissue homogenates. *Comp. Biochem. Physiol.* 63B:67-72.
- 321 Norton, R.S.; de Rome, P. 1980. ^{13}C NMR-study of osmoregulatory metabolites in the marine mollusc *Tapes wallingi*. *Experientia* 36:522-524.
- 322 Storey, K.B.; Miceli, M.; Butler, K.W.; Smith, I.C.P.; Deslauriers, R. 1984. ^{31}P -NMR studies of the freeze-tolerant larvae of the gall fly, *Eurosta solidaginis*. *Eur. J. Biochem.* 142:591-595.
- 323 Thompson, S.N.; Lee, R.W.-K. 1988. NMR studies on gluconeogenesis and metabolism of [^{13}C]2-pyruvate in *Manduca sexta*. *Insect Biochem.* 18:21-27.
- 324 Thompson, S.N.; Lee, R.W.-K.; Beckage, N.E. 1989. Characterization of the ^{31}P NMR spectrum of *Manduca sexta* and effects of antimetabolites. *Insect Biochem.* 19:323-326.
- 325 Wasylshen, R.E.; Novak, M. 1983. Natural abundance ^{13}C nuclear magnetic resonance studies of live cestodes. *Comp. Biochem. Physiol.* 74B:303-306.

VIII (b). Chemistry of Biopolymers

- 326 Duff, G.A.; Roberts, J.E.; Foster, N. 1988. Analysis of the structure of synthetic and natural melanins by solid-phase NMR. *Biochemistry* 27:7112-7116.
- 327 Hackman, R.H. 1986. The chemical nature of the outer epicuticle from *Lucilia cuprina* larvae. *Insect Biochem.* 16:911-916.
- 328 Kramer, K.J.; Bork, V.; Schaefer, J.; Morgan, T.D.; Hopkins, T.L. 1989. Solid state ^{13}C nuclear magnetic resonance and chemical analyses of insect noncuticular sclerotized support structures: mantid oothecae and cocoon silks. *Insect Biochem.* 19:69-77.
- 329 Kramer, K.J.; Morgan, T.D.; Hopkins, T.L.; Christensen, A.M.; Schaefer, J. 1989. Solid-state ^{13}C -NMR and diphenol analyses of sclerotized cuticles from stored product Coleoptera. *Insect Biochem.* 19:753-757.
- 330 Peter, M.G.; Grün, L.; Förster, H. 1984. CP/MAS- ^{13}C -NMR spectra of sclerotized insect cuticle and of chitin. *Angew. Chem. Int. Ed. Engl.* 23:638-639.
-

331 Schaefer, J.; Kramer, K.J.; Garbow, J.R.; Jacob, G.S.; Stejskal, E.O.; Hopkins, T.L.; Speirs, R.D. 1987. Aromatic cross-links in insect cuticle: detection by solid-state ^{13}C and ^{15}N NMR. *Science* 235:1200-1204.

332 Vincent, J.F.V.; Ablett, S. 1987. Hydration and tanning in insect cuticle. *J. Insect Physiol.* 33:973-979.

IX. Wood

IX (a). Chemistry of Structural Biopolymers

333 Attalla, M.I.; Serra, R.G.; Vassallo, A.M.; Wilson, M.A. 1988. Structure of ancient buried wood from *Phyllocladus trichomanoides*. *Org. Geochem.* 12:235-244.

334 Barron, P.F.; Frost, R.L.; Doimo, L.; Kennedy, M.J. 1985. ^{13}C -CP/MAS NMR examination of some Australian woods and their chemical and biochemical degradation residues. *J. Macromol. Sci.-Chem.* A22:303-322.

335 Botto, R.E. 1988. Synthesis and characterization of [^{13}C]lignins. *Macromolecules* 21:1246-1250.

336 Ellwardt, P.-C.; Haider, K.; Ernst, L. 1981. Untersuchungen des mikrobiellen Ligninabbaues durch ^{13}C -NMR-Spektroskopie an spezifisch ^{13}C -angereichertem DHP-Lignin aus Coniferylalkohol. *Holzforschung* 35:103-109.

337 Fyfe, C.A.; Dudley, R.L.; Stephenson, P.J.; Deslandes, Y.; Hamer, G.K.; Marchessault, R.H. 1983. Application of high-resolution solid-state NMR with cross-polarization/magic-angle spinning (CP/MAS) techniques to cellulose chemistry. *JMS-Rev. Macromol. Chem. Phys.* C23:187-216.

338 Gerasimowicz, W.V.; Hicks, K.B.; Pfeffer, P.E. 1984. Evidence for the existence of associated lignin-carbohydrate polymers as revealed by carbon-13 CPMAS solid-state NMR spectroscopy. *Macromolecules* 17:2597-2603.

339 Hatcher, P.G. 1987. Chemical structural studies of natural lignin by dipolar dephasing solid-state ^{13}C nuclear magnetic resonance. *Org. Geochem.* 11:31-39.

340 Hatfield, G.R.; Maciel, G.E.; Erbatur, O.; Erbatur, G. 1987. Qualitative and quantitative analysis of solid lignin samples by carbon-13 nuclear magnetic resonance spectrometry. *Anal. Chem.* 59:172-179.

341 Hatfield, G.R.; Sardashti, M.; Maciel, G.E. 1987. Analysis of molecular orientational order in solid samples by nuclear magnetic resonance: application to lignin and cellulose in wood. *Anal. Chem.* 59:1659-1664.

342 Haw, J.F.; Maciel, G.E.; Schroeder, H.A. 1984. Carbon-13 nuclear magnetic resonance spectrometric study of wood and wood pulping with cross polarization and magic-angle spinning. *Anal. Chem.* 56:1323-1329.

343 Hemmingson, J.A.; Newman, R.H. 1985. A CP/MAS ^{13}C NMR study of the effect of steam explosion processes on wood composition and structure. *J. Wood Chem. Technol.* 5:159-188.

344 Isogai, A.; Usuda, M.; Kato, T.; Uryu, T.; Atalla, R.H. 1989. Solid-state CP/MAS ^{13}C NMR study of cellulose polymorphs. *Macromolecules* 22:3168-3172.

-
- 345 Kolodziejski, W.; Frye, J.S.; Maciel, G.E. 1982. Carbon-13 nuclear magnetic resonance spectrometry with cross polarization and magic-angle spinning for analysis of lodgepole pine wood. *Anal. Chem.* 54:1419-1424.
- 346 Lapierre, C.; Gaudillere, J.P.; Monties, B.; Guittet, E.; Rolando, C.; Lallemand, J.Y. 1983. Enrichissement photosynthétique en carbone 13 de lignines de peuplier: caractérisation préliminaire par acidolyse et RMN ^{13}C . *Holzforschung* 37:217-224.
- 347 Lapierre, C.; Lallemand, J.Y.; Monties, B. 1982. Evidence of poplar lignin heterogeneity by combination of ^{13}C and ^1H NMR spectroscopy. *Holzforschung* 36:275-282.
- 348 Lapierre, C.; Monties, B.; Guittet, E.; Lallemand, J.Y. 1984. Photosynthetically ^{13}C -labelled poplar lignins: ^{13}C NMR experiments. *Holzforschung* 38:333-342.
- 349 Leary, G.J.; Morgan, K.R.; Newman, R.H. 1986. A ^{13}C CP/MAS NMR comparison of wood fractions from spruce. *Holzforschung* 40:221-224.
- 350 Leary, G.J.; Newman, R.H.; Morgan, K.R. 1986. A carbon-13 nuclear magnetic resonance study of chemical processes involved in the isolation of Klason lignin. *Holzforschung* 40:267-272.
- 351 Lewis, N.G.; Newman, J.; Just, G.; Ripmeister, J. 1987. Determination of bonding patterns of ^{13}C specifically enriched dehydrogenatively polymerized lignin in solution and solid state. *Macromolecules* 20:1752-1756.
- 352 Lewis, N.G.; Razal, R.A.; Dhara, K.P.; Yamamoto, E.; Bokelman, G.H.; Wooten, J.B. 1988. Incorporation of [2- ^{13}C]ferulic acid, a lignin precursor, into *Leucaena leucocephala* and its analysis by solid state ^{13}C N.M.R. spectroscopy. *J. Chem. Soc., Chem. Commun.* 1626-1628.
- 353 Manders, W.F. 1987. Solid-state ^{13}C NMR determination of the syringyl/guaiacyl ratio in hardwoods. *Holzforschung* 41:13-18.
- 354 Morgan, K.R.; Newman, R.H. 1987. Estimation of the tannin content of eucalypts and other hardwoods by carbon-13 nuclear magnetic resonance. *Appita* 40:450-454.
- 355 Nieminen, M.O.J.; Pulkkinen, E.; Rahkamaa, E. 1989. Determination of hydroxyl groups in kraft pine lignin by silicon-29 NMR spectroscopy. *Holzforschung* 43:303-307.
- 356 Preston, C.M.; Sollins, P.; Sayer, B.G. 1990. Changes in organic components for fallen logs in old-growth Douglas-fir forests monitored by ^{13}C nuclear magnetic resonance spectroscopy. *Can. J. For. Res.* Vol. 20, in press.
- 357 Robert, D.; Chen, C.-L. 1989. Biodegradation of lignin in spruce wood by *Phanerochaete chrysosporium*: quantitative analysis of biodegraded spruce lignins by ^{13}C NMR spectroscopy. *Holzforschung* 43:323-332.
- 358 Taylor, M.G.; Deslandes, Y.; Bluhm, T.; Marchessault, R.H.; Vincendon, M.; Saint-Germain, J. 1983. Solid state ^{13}C NMR characterization of wood. *Tappi Journal* 66:92-94.
- 359 Tekely, P.; Vignon, M.R. 1987. Proton T_1 and T_2 relaxation times of wood components using ^{13}C CP/MAS NMR. *J. Polymer Sci.: Part C: Polymer Lett.* 25:257-261.
- 360 Willis, J.M.; Herring, F.G. 1987. Effect of water in the ^{13}C CP/MAS NMR spectrum of white spruce wood. *Macromolecules* 20:1554-1556.
-

-
- 361 Wilson, M.A.; Hatcher, P.G. 1988. Detection of tannins in modern and fossil barks and in plant residues by high-resolution solid-state ^{13}C nuclear magnetic resonance. *Org. Geochem.* 12:539-546.

IX (b). Imaging

- 362 Hailey, J.R.; Morris, P.I. 1987. Application of scanning and imaging techniques to assess decay and wood quality in logs and standing trees. Canadian Forest Service/Alberta Forestry Service Report No. Fo 42-91/41-1988E.
- 363 Hall, L.D.; Rajanayagam, V. 1986. Evaluation of the distribution of water in wood by use of three dimensional proton NMR volume imaging. *Wood Sci. Technol.* 20:329-333.
- 364 Hall, L.D.; Rajanayagam, V.; Stewart, W.A.; Steiner, P.R. 1986. Magnetic resonance imaging of wood. *Can. J. For. Res.* 16:423-426.
- 365 Hall, L.D.; Rajanayagam, V.; Stewart, W.A.; Steiner, P.R.; Chow, S. 1986. Detection of hidden morphology of wood by magnetic resonance imaging. *Can. J. For. Res.* 16:684-687.
- 366 Menon, R.S.; MacKay, A.L.; Hailey, J.R.T.; Bloom, M.; Burgess, A.E.; Swanson, J.S. 1987. An NMR determination of the physiological water distribution in wood during drying. *J. Appl. Polymer Sci.* 33:1141-1155.
- 367 Wang, P.C.; Chang, S.J. 1986. Nuclear magnetic resonance imaging of wood. *Wood Fiber Sci.* 18:308-314.

X. Soils

X (a). General Reviews

- 368 Axelson, D.E. 1985. Solid State Nuclear Magnetic Resonance of Fossil Fuels: An Experimental Approach. Published by Multiscience Publications Limited in cooperation with CANMET, Energy, Mines and Resources Canada and the Canadian Government Publishing Centre, Supply and Services Canada. 226 p.
- 369 Wershaw, R.L.; Mikita, M.A. 1987. NMR of Humic Substances and Coal. Techniques, Problems and Solutions. Chelsea, Mich., Lewis Publishers, Inc. 236 p.
- 370 Wilson, M.A. 1987. N.M.R. Techniques and Applications in Geochemistry and Soil Chemistry. Oxford, Pergamon Press. 353 p.

X (b). Mineral Soils - Whole Soils, Chemical Fractions and Physical Separates

- 371 Arshad, M.A.; Ripmeester, J.A.; Schnitzer, M. 1988. Attempts to improve solid state ^{13}C NMR spectra of whole mineral soils. *Can. J. Soil Sci.* 68:593-602.
- 372 Arshad, M.A.; Schnitzer, M. 1989. Chemical characteristics of humic acids from five soils in Kenya. *Z. Pflanzenernähr. Bodenk.* 152: 11-16.

-
- 373 Arshad, M.A.; Schnitzer, M.; Preston, C.M. 1988. Characterization of humic acids from termite mounds and surrounding soils, Kenya. *Geoderma* 42:213-225.
- 374 Benzing-Purdie, L.; Ripmeester, J.A.; Preston, C.M. 1983. Elucidation of the nitrogen forms in melanoidins and humic acid by nitrogen-15 cross polarization-magic angle spinning nuclear magnetic resonance spectroscopy. *J. Agric. Food Chem.* 31:913-915.
- 375 Catroux, G.; Schnitzer, M. 1987. Chemical, spectroscopic, and biological characteristics of the organic matter in particle size fractions separated from an Aquoll. *Soil Sci. Soc. Am. J.* 51:1200-1207.
- 376 Hatcher, P.G.; Schnitzer, M.; Vassallo, A.M.; Wilson, M.A. 1989. The chemical structure of highly aromatic humic acids in three volcanic ash soils as determined by dipolar dephasing NMR studies. *Geochim. Cosmochim. Acta* 53:125-130.
- 377 Lobartini, J.C.; Tan, K.H. 1988. Differences in humic acid characteristics as determined by carbon-13 nuclear magnetic resonance, scanning electron microscopy, and infrared analysis. *Soil Sci. Soc. Am. J.* 52:125-130.
- 378 Ma'shum, M.; Tate, M.E.; Jones, G.P.; Oades, J.M. 1988. Extraction and characterization of water-repellent materials from Australian soils. *J. Soil Sci.* 39:99-110.
- 379 Newman, R.H.; Tate, K.R.; Barron, P.F.; Wilson, M.A. 1980. Towards a direct, non-destructive method of characterising soil humic substances using ^{13}C N.M.R. *J. Soil Sci.* 31:623-631.
- 380 Oades, J.M.; Vassallo, A.M.; Waters, A.G.; Wilson, M.A. 1987. Characterization of organic matter in particle size and density fractions from a red-brown earth by solid-state ^{13}C N.M.R. *Aust. J. Soil Res.* 25:71-82.
- 381 Oades, J.M.; Waters, A.G.; Vassallo, A.M.; Wilson, M.A.; Jones, G.P. 1988. Influence of management on the composition of organic matter in a red-brown earth as shown by ^{13}C nuclear magnetic resonance. *Aust. J. Soil Res.* 26:289-299.
- 382 Preston, C.M. 1987. Review of solution NMR of humic substances. Pages 3-32 in R.L. Wershaw, and M. A. Mikita, editors. *NMR of Humic Substances and Coal*. Chelsea, MI, Lewis Publishers. 236 p.
- 383 Preston, C.M.; Blackwell, B.A. 1985. Carbon-13 nuclear magnetic resonance for a humic and a fulvic acid: signal-to-noise optimization, quantitation, and spin-echo techniques. *Soil Sci.* 139:88-96.
- 384 Preston, C.M.; Ripmeester, J.A. 1983. ^{13}C -labelling for NMR studies of soils: CPMAS NMR observation of ^{13}C -acetate transformation in a mineral soil. *Can. J. Soil Sci.* 63:495-500.
- 385 Preston, C.M.; Schnitzer, M. 1984. Effects of chemical modifications and extractants on the carbon-13 NMR spectra of humic materials. *Soil Sci. Soc. Am. J.* 48:305-311.
- 386 Preston, C.M.; Schnitzer, M. 1987. ^{13}C NMR of humic substances: pH and solvent effects. *J. Soil Sci.* 38:667-678.
- 387 Preston, C.M.; Schnitzer, M.; Ripmeester, J.A. 1989. A spectroscopic and chemical investigation on the de-ashing of a humin. *Soil Sci. Soc. Am. J.* 53:1442-1447.
- 388 Schnitzer, M.; Preston, C.M. 1983. Effects of acid hydrolysis on the ^{13}C NMR spectra of humic substances. *Plant Soil* 75:201-211.
-

-
- 389 Schnitzer, M.; Preston, C.M. 1986. Analysis of humic acids by solution and solid-state carbon-13 nuclear magnetic resonance. *Soil Sci. Soc. Am. J.* 50:326-331.
- 390 Schnitzer, M.; Preston, C.M. 1987. Supercritical gas extraction of a soil with solvents of increasing polarities. *Soil Sci. Soc. Am. J.* 51:639-646.
- 391 Schnitzer, M.; Ripmeester, J.A.; Kodama, H. 1988. Characterization of the organic matter associated with a soil clay. *Soil Sci.* 145:448-454.
- 392 Skjemstad, J.O.; Dalal, R.C. 1987. Spectroscopic and chemical differences in organic matter of two Vertisols subjected to long periods of cultivation. *Aust. J. Soil Res.* 25:323-335.
- 393 Skjemstad, J.O.; Dalal, R.C.; Barron, P.F. 1986. Spectroscopic investigations of cultivation effects on organic matter of Vertisols. *Soil Sci. Soc. Am. J.* 50:354-359.
- 394 Skjemstad, J.O.; Frost, R.L.; Barron, P.F. 1983. Structural units in humic acids from south-eastern Queensland soils as determined by ^{13}C NMR spectroscopy. *Aust. J. Soil Res.* 21:539-547.
- 395 Stearman, G.K.; Lewis, R.J.; Tortorelli, L.J.; Tyler, D.D. 1989. Characterization of humic acid from no-tilled and tilled soils using carbon-13 nuclear magnetic resonance. *Soil Sci. Soc. Am. J.* 53:744-749.
- 396 Stearman, G.K.; Lewis, R.J.; Tortorelli, L.J.; Tyler, D.D. 1989. Herbicide reactivity of soil organic matter fractions in no-tilled and tilled cotton. *Soil Sci. Soc. Am. J.* 53:1690-1694.
- 397 Theng, B.K.G.; Churchman, G.J.; Newman, R.H. 1986. The occurrence of interlayer clay-organic complexes in two New Zealand soils. *Soil Sci.* 142:262-266.
- 398 Thorn, K.A.; Steelink, C.; Wershaw, R.L. 1987. Methylation patterns of aquatic humic substances determined by ^{13}C NMR spectroscopy. *Org. Geochem.* 11:123-137.
- 399 Vassallo, A.M.; Wilson, M.A.; Collin, P.J.; Oades, J.M.; Waters, A.G.; Malcolm, R.L. 1987. Structural analysis of geochemical samples by solid-state nuclear magnetic resonance spectrometry. Role of paramagnetic material. *Anal. Chem.* 59:558-562.
- 400 Wilson, M.A.; Collin, P.J.; Tate, K.R. 1983. ^1H -nuclear magnetic resonance study of a soil humic acid. *J. Soil Sci.* 34:297-304.
- 401 Wilson, M.A.; Vassallo, A.M.; Perdue, E.M.; Reuter, J.H. 1987. Compositional and solid-state nuclear magnetic resonance study of humic and fulvic acid fractions of soil organic matter. *Anal. Chem.* 59:551-558.

X (c). Forest Soils and Organic Horizons

- 402 Arshad, M.A.; Schnitzer, M.; Preston, C. 1987. Characteristics of a termite fungus comb studied by chemical and spectroscopic methods. *Soil Biol. Biochem.* 19:227-230.
- 403 Beudert, G.; Kögel-Knabner, I.; Zech, W. 1989. Micromorphological, wet-chemical and ^{13}C NMR spectroscopic characterization of density fractionated forest soils. *Sci. Tot. Environ.* 81/82:401-408.
- 404 Candler, R.; Zech, W.; Alt, H.G. 1988. Characterization of water-soluble organic substances from a typic dystrochrept under spruce using GPC, IR, ^1H NMR, and ^{13}C NMR spectroscopy. *Soil Sci.* 146:445-452.

-
- 405 Candler, R.; Zech, W.; Alt, H.G. 1989. A comparison of water soluble organic substances in acid soils under beech and spruce in NE-Bavaria. *Z. Pflanzenernähr. Bodenk.* 152:61-65.
- 406 Fründ, R.; Lüdemann, H.-D.; Zech, W. 1988. The separation of low molecular weight humic acid fractions and their characterisation by HR-C-13-NMR in solution. *Z. Pflanzenernähr. Bodenk.* 151:303-305.
- 407 Hammond, T.E.; Cory, D.G.; Ritchey, W.M.; Morita, H. 1985. High resolution solid state ^{13}C n.m.r. of Canadian peats. *Fuel* 64:1687-1695.
- 408 Hempfling, R.; Zech, W.; Schulten, H.-R. 1988. Chemical composition of the organic matter in forest soils: 2. Moder profile. *Soil Sci.* 146:262-276.
- 409 Hempfling, R.; Ziegler, F.; Zech, W.; Schulten, H.-R. 1987. Litter decomposition and humification in acidic forest soils studied by chemical degradation, IR and NMR spectroscopy and pyrolysis field ionization mass spectrometry. *Z. Pflanzenernähr. Bodenk.* 150:179-186.
- 410 Kögel, I.; Hempfling, R.; Zech, W.; Hatcher, P.G.; Schulten, H.-R. 1988. Chemical composition of the organic matter in forest soils: 1. Forest litter. *Soil Sci.* 146:124-136.
- 411 Kögel-Knabner, I.; Hatcher, P.G. 1989. Characterization of alkyl carbon in forest soils by CPMAS ^{13}C NMR spectroscopy and dipolar dephasing. *Sci. Tot. Environ.* 81/82:169-177.
- 412 Kögel-Knabner, I.; Zech, W.; Hatcher, P.G. 1988. Chemical composition of the organic matter in forest soils: the humus layer. *Z. Pflanzenernähr. Bodenk.* 151:331-340.
- 413 Nordén, B.; Albano, C. 1989. Principal components analysis of complex n.m.r. spectra from heterogeneous material. *Fuel* 68:771-775.
- 414 Ogner, G. 1985. A comparison of four different raw humus types in Norway using chemical degradations and CPMAS ^{13}C NMR spectroscopy. *Geoderma* 35:343-353.
- 415 Orem, W.H.; Hatcher, P.G. 1987. Early diagenesis of organic matter in a sawgrass peat from The Everglades, Florida. *Int. J. Coal Geol.* 8:33-54.
- 416 Post, B.; Hempfling, R.; Klamberg, H.; Schulten, H.-R. 1988. Zur Charakterisierung von Boden-Huminstoffen. *Fresenius Z. Anal. Chem.* 331:273-281.
- 417 Preston, C.M. 1987. The application of NMR spectroscopy to organic soils and horizons. Pages 121-133 in J. de Vries, coordinator. *Proceedings of the Eleventh Meeting of the British Columbia Soil Science Workshop, Organic Soils and Horizons*, held at the University of British Columbia, Feb. 19-20, 1987. Victoria, B.C., Ministry of Agriculture and Fisheries.
- 418 Preston, C.M.; Axelson, D.E.; Lévesque, M.; Mathur, S.P.; Diné, H.; Dudley, R.L. 1989. Carbon-13 NMR and chemical characterization of particle-size separates of peats differing in degree of decomposition. *Org. Geochem.* 14:393-403.
- 419 Preston, C.M.; Dudley, R.L.; Fyfe, C.A.; Mathur, S.P. 1984. Effects of variations in contact times and copper contents in a ^{13}C CPMAS NMR study of samples of four organic soils. *Geoderma* 33:245-253.
- 420 Preston, C.M.; Ripmeester, J.A. 1982. Application of solution and solid-state ^{13}C NMR to four organic soils, their humic acids, fulvic acids, humins and hydrolysis residues. *Can. J. Spectrosc.* 27:99-105.
-

-
- 421 Preston, C.M.; Shipitalo, S.-E.; Dudley, R.L.; Fyfe, C.A.; Mathur, S.P.; Lévesque, M. 1987. Comparison of ^{13}C CPMAS NMR and chemical techniques for measuring the degree of decomposition in virgin and cultivated peat profiles. *Can. J. Soil Sci.* 67:187-198.
- 422 Wilson, M.A. 1984. Soil organic matter maps by nuclear magnetic resonance. *J. Soil Sci.* 35:209-215.
- 423 Wilson, M.A.; Goh, K.M.; Collin, P.J.; Greenfield, L.G. 1986. Origins of humus variation. *Org. Geochem.* 9:225-231.
- 424 Wilson, M.A.; Heng, S.; Goh, K.M.; Pugmire, R.J.; Grant, D.M. 1983. Studies of litter and acid insoluble soil organic matter fractions using ^{13}C -cross polarization nuclear magnetic resonance spectroscopy with magic angle spinning. *J. Soil Sci.* 34:83-97.
- 425 Wilson, M.A.; Pugmire, R.J.; Grant, D.M. 1983. Nuclear magnetic resonance spectroscopy of soils and related materials. Relaxation of ^{13}C nuclei in cross polarization nuclear magnetic resonance experiments. *Org. Geochem.* 5:121-129.
- 426 Zech, W.; Johansson, M.-B.; Haumaier, L.; Malcolm, R.L. 1987. CPMAS ^{13}C NMR and IR spectra of spruce and pine litter and of the Klason lignin fraction at different stages of decomposition. *Z. Pflanzenernähr. Bodenk.* 150:262-265.
- 427 Zech, W.; Kögel, I.; Zucker, A.; Alt, H. 1985. CP-MAS- ^{13}C -NMR Spektren organischer Lagen einer Tangelrendzina. *Z. Pflanzenernähr. Bodenk.* 148:481-488.

X (d). Composts, Sludges and Plant Material

- 428 Almendros, G.; Fründ, R.; Gonzales-Vila, F.J.; Lüdemann, H.-D.; Martin, F. 1987. NMR and ESR investigation of the humification process in defined vegetable starting materials. *Z. Pflanzenernähr. Bodenk.* 150:201-207.
- 429 Cogle, A. L.; Saffigna, P. G.; Barron, P. F. 1989. The use of ^{13}C -NMR for studies of wheat straw decomposition. *Plant Soil* 113: 125-128.
- 430 Efloson, R.M.; Ripmeester, J.A.; Cyr, N.; Milligan, L.P.; Mathison, G. 1984. Nutritional evaluation of forages by high-resolution solid state ^{13}C -NMR. *Can. J. Anim. Sci.* 64:93-102.
- 431 Hinedi, Z.R.; Chang, A.C.; Lee, R.W.K. 1988. Mineralization of phosphorus in sludge-amended soils monitored by phosphorus-31-nuclear magnetic resonance spectroscopy. *Soil Sci. Soc. Am. J.* 52:1593-1596.
- 432 Hinedi, Z.R.; Chang, A.C.; Lee, R.W.K. 1989. Characterization of phosphorus in sludge extracts using phosphorus-31 nuclear magnetic resonance spectroscopy. *J. Environ. Qual.* 18:323-329.
- 433 Inbar, Y.; Chen, Y.; Hadar, Y. 1989. Solid-state carbon-13 nuclear magnetic resonance and infrared spectroscopy of composted organic matter. *Soil Sci. Soc. Am. J.* 53:1695-1701.
- 434 Maciel, G.E.; Haw, J.F.; Smith, D.H.; Gabrielsen, B.C.; Hatfield, G.R. 1985. Carbon-13 nuclear magnetic resonance of herbaceous plants and their components, using cross polarization and magic angle spinning. *J. Agric. Food Chem.* 33:185-191.
- 435 Pfeffer, P.E.; Gerasimowicz, W.V.; Piotrowski, E.G. 1984. Effect of paramagnetic iron on quantitation in carbon-13 cross polarization magic angle spinning nuclear magnetic resonance spectrometry of heterogeneous environmental matrices. *Anal. Chem.* 56:734-741.

-
- 436 Piotrowski, E.G.; Valentine, K.M.; Pfeffer, P.E. 1984. Solid-state ^{13}C , cross-polarization, "magic-angle" spinning, NMR spectroscopy studies of sewage sludge. *Soil Sci.* 137:194-203.
- 437 Preston, C.M.; Ripmeester, J.A.; Mathur, S.P.; Lévesque, M. 1986. Application of solution and solid-state multinuclear NMR to a peat-based composting system for fish and crab scrap. *Can. J. Spectrosc.* 31:63-69.

X (e). Chemical Models for Soil Organic Matter

- 438 Benzing-Purdie, L.; Ripmeester, J.A. 1983. Melanoidins and soil organic matter: evidence of strong similarities revealed by ^{13}C CP-MAS NMR. *Soil Sci. Soc. Am. J.* 47:56-61.
- 439 Hänninen, K.I.; Klöcking, R.; Helbig, A. 1987. Synthesis and characterization of humic acid-like polymers. *Sci. Tot. Environ.* 62:201-210.
- 440 Ikan, R.; Rubinsztain, Y.; Ioselis, P.; Aizenshtat, Z.; Pugmire, R.; Anderson, L.L.; Woolfenden, W.R. 1986. Carbon-13 cross polarized magic-angle samples spinning nuclear magnetic resonance of melanoidins. *Org. Geochem.* 9:199-212.
- 441 McBride, M.B.; Sikora, F.J.; Wesselink, L.G. 1988. Complexation and catalyzed oxidative polymerization of catechol by aluminum in acidic solution. *Soil Sci. Soc. Am. J.* 52:985-993.
- 442 Preston, C.M.; Rauthan, B.S.; Rodger, C.; Ripmeester, J.A. 1982. A hydrogen-1, carbon-13, and nitrogen-15 nuclear magnetic resonance study of *p*-benzoquinone polymers incorporating amino nitrogen compounds ("synthetic humic acids"). *Soil Sci.* 134:277-293.
- 443 Schnitzer, M.; Chan, Y.K. 1986. Structural characteristics of a fungal melanin and a soil humic acid. *Soil Sci. Soc. Am. J.* 50:67-71.

X (f). Phosphorus in Soil and Composts

- 444 Adams, M.A.; Byrne, L.T. 1989. ^{31}P -NMR analysis of phosphorus compounds in extracts of surface soils from selected karri (*Eucalyptus diversicolor* F. Muell.) forests. *Soil Biol. Biochem.* 21:523-528.
- 445 Condron, L.M.; Goh, K.M.; Newman, R.H. 1985. Nature and distribution of soil phosphorus as revealed by a sequential extraction method followed by ^{31}P nuclear magnetic resonance analysis. *J. Soil Sci.* 36:199-207.
- 446 Emsley, J.; Niazi, S. 1983. The analysis of soil phosphorus by ICP and ^{31}P NMR spectroscopy. *Phosphorus and Sulfur* 16:303-312.
- 447 Hawkes, G.E.; Powlson, D.S.; Randall, E.W.; Tate, K.R. 1984. A ^{31}P nuclear magnetic resonance study of the phosphorus species in alkali extracts of soils from long-term field experiments. *J. Soil Sci.* 35:35-45.
- 448 McCarty, G.W.; Bremner, J.M. 1989. Formation of phosphoryl triamide by decomposition of thiophosphoryl triamide in soil. *Biol. Fertil. Soils* 8:290-292.
- 449 McCarty, G.W.; Bremner, J.M.; Chai, H.S. 1989. Effect of *N*-(*n*-butyl)thiophosphoric triamide on hydrolysis of urea by plant, microbial, and soil urease. *Biol. Fertil. Soils* 8:123-127.
-

-
- 450 Newman, R.H.; Tate, K.R. 1980. Soil phosphorus characterisation by ^{31}P nuclear magnetic resonance. *Commun. Soil Sci. Plant Anal.* 11:835-842.
- 451 Ogner, G. 1983. ^{31}P -NMR spectra of humic acids: a comparison of four different raw humus types in Norway. *Geoderma* 29:215-219.
- 452 Ogner, G.; Langerud, B.R. 1983. ^{31}P -NMR of humic acids isolated from two different peat soils in Norway. *Acta Agric. Scand.* 33:143-144.
- 453 Tate, K.R.; Newman, R.H. 1982. Phosphorus fractions of a climosequence of soils in New Zealand tussock grassland. *Soil Biol. Biochem.* 14:191-196.
- 454 Zech, W.; Alt, H.G.; Haumaier, L.; Blasek, R. 1987. Characterization of phosphorus fractions in mountain soils of the Bavarian Alps by ^{31}P NMR spectroscopy. *Z. Pflanzenernähr. Bodenk.* 150:119-123.
- 455 Zech, W.; Alt, H.G.; Zucker, A.; Kögel, I. 1985. ^{31}P -NMR-spectroscopic investigations of NaOH-extracts from soils with different land use in Yucatan (Mexico). *Z. Pflanzenernähr. Bodenk.* 148:626-632.

X (g). Inorganic Components of Soil

- 456 Alma, N.C.M.; Hays, G.R.; Samoson, A.V.; Lippmaa, E.T. 1984. Characterization of synthetic dioctahedral clays by solid-state silicon-29 and aluminum-27 nuclear magnetic resonance spectroscopy. *Anal. Chem.* 56:729-733.
- 457 Barron, P.F.; Frost, R.L.; Skjemstad, J.O.; Koppi, A.J. 1983. Detection of two silicon environments in kaolins by solid-state ^{29}Si NMR. *Nature* 302:49-50.
- 458 Barron, P.F.; Wilson, M.A.; Campbell, A.S.; Frost, R.L. 1982. Detection of imogolite in soils using solid state ^{29}Si NMR. *Nature* 299:616-618.
- 459 Bertsch, P.M.; Thomas, G.W.; Barnhisel, R.I. 1986. Characterization of hydroxy-aluminum solutions by aluminum-27 nuclear magnetic resonance spectroscopy. *Soil Sci. Soc. Am. J.* 50:825-830.
- 460 Bertsch, P.M.; Layton, W.J.; Barnhisel, R.I. 1986. Speciation of hydroxy-aluminum solutions by wet chemical and aluminum-27 NMR methods. *Soil Sci. Soc. Am. J.* 50:1449-1454.
- 461 Corbin, D.R.; Burgess, B.F. Jr.; Vega, A.J.; Farlee, R.D. 1987. Comparison of analytical techniques for the determination of silicon and aluminum content in zeolites. *Anal. Chem.* 59:2722-2728.
- 462 Fyfe, C.A.; Gobbi, G.C.; Hartman, J.S.; Klinowski, J.; Thomas, J.M. 1982. Solid-state magic-angle spinning aluminum-27 nuclear magnetic resonance studies of zeolites using a 400-MHz high-resolution spectrometer. *J. Phys. Chem.* 86:1247-1250.
- 463 Fyfe, C.A.; Gobbi, G.C.; Klinowski, J.; Thomas, J.M.; Ramdas, S. 1982. Resolving crystallographically distinct tetrahedral sites in silicalite and ZSM-5 by solid-state NMR. *Nature* 296:530-533.
- 464 Wilson, M.A.; Barron, P.F.; Campbell, A.S. 1984. Detection of aluminium coordination in soils and clay fractions using ^{27}Al magic angle spinning n.m.r. *J. Soil Sci.* 35:201-207.

XI. Pesticides (Glyphosate)

- 465 Barlow, P.N.; Appleyard, R.J.; Wilson, B.J.O.; Evans, J.N.S. 1989. Direct observation of the enzyme-intermediate complex of 5-enolpyruvylshikimate-3-phosphate synthase by ^{13}C NMR spectroscopy. *Biochemistry* 28:7985-7991.
- 466 Castellino, S.; Leo, G.C.; Sammons, R.D.; Sikorski, J.A. 1989. ^{31}P , ^{15}N , and ^{13}C NMR of glyphosate: comparison of pH titrations to the herbicidal dead-end complex with 5-enolpyruvylshikimate-3-phosphate synthase. *Biochemistry* 28:3856-3868.
- 467 Greenhalgh, R.; Blackwell, B.A.; Preston, C.M.; Murray, W.J. 1983. Phosphorus-31 nuclear magnetic resonance analysis of technical organophosphorus insecticides for toxic contaminants. *J. Agric. Food Chem.* 31:710-713
- 468 Jacob, G.S.; Garbow, J.R.; Schaefer, J.; Kishore, G.M. 1987. Solid-state NMR studies of regulation of *N*-(phosphonomethyl)glycine and glycine metabolism in *Pseudomonas* sp. strain PG2982. *J. Biol. Chem.* 262:1552-1557.
- 469 Jacob, G.S.; Schaefer, J.; Stejskal, E.O.; McKay, R.A. 1985. Solid-state NMR determination of glyphosate metabolism in a *Pseudomonas* sp. *J. Biol. Chem.* 260:5899-5905.
- 470 Rueppel, M.L.; Brightwell, B.B.; Schaefer, J.; Marvel, J.T. 1977. Metabolism and degradation of glyphosate in soil and water. *J. Agric. Food Chem.* 25:517-528.
- 471 Rueppel, M.L.; Marvel, J.T. 1976. ^1H and ^{31}P NMR spectra of substituted methylphosphonic acids with indirect determination of ^{31}P shifts. *Org. Mag. Res.* 8:19-20.

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